Modeling and Adjusting for Weather Effects and Seasonal Noise in U.S. Monthly Regional Housing Starts

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(results in collaboration with Brian Monsell (BLS) and Thomas Trimbur)

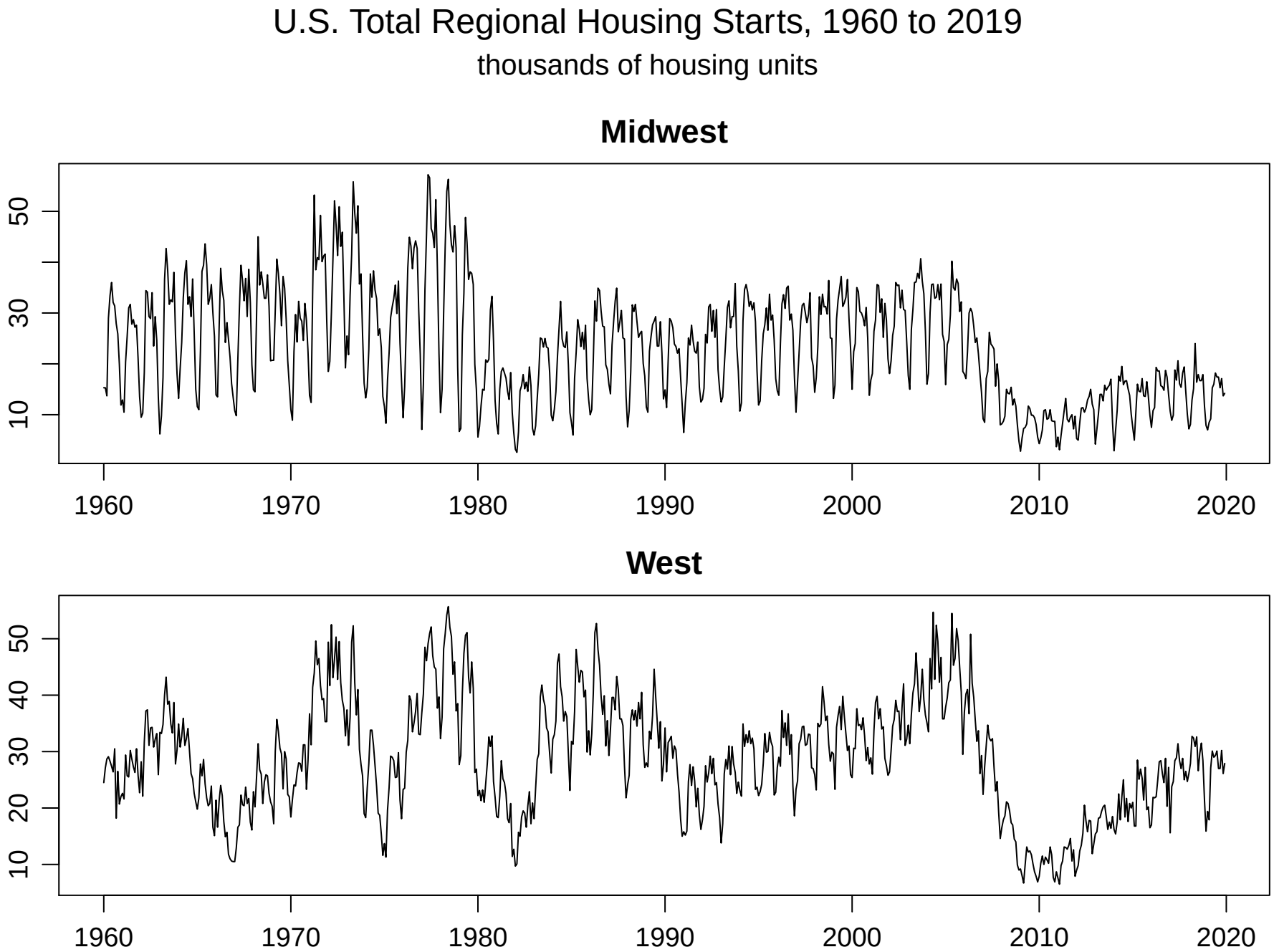
Seasonal Adjustment Practitioners Workshop, September 11, 2024

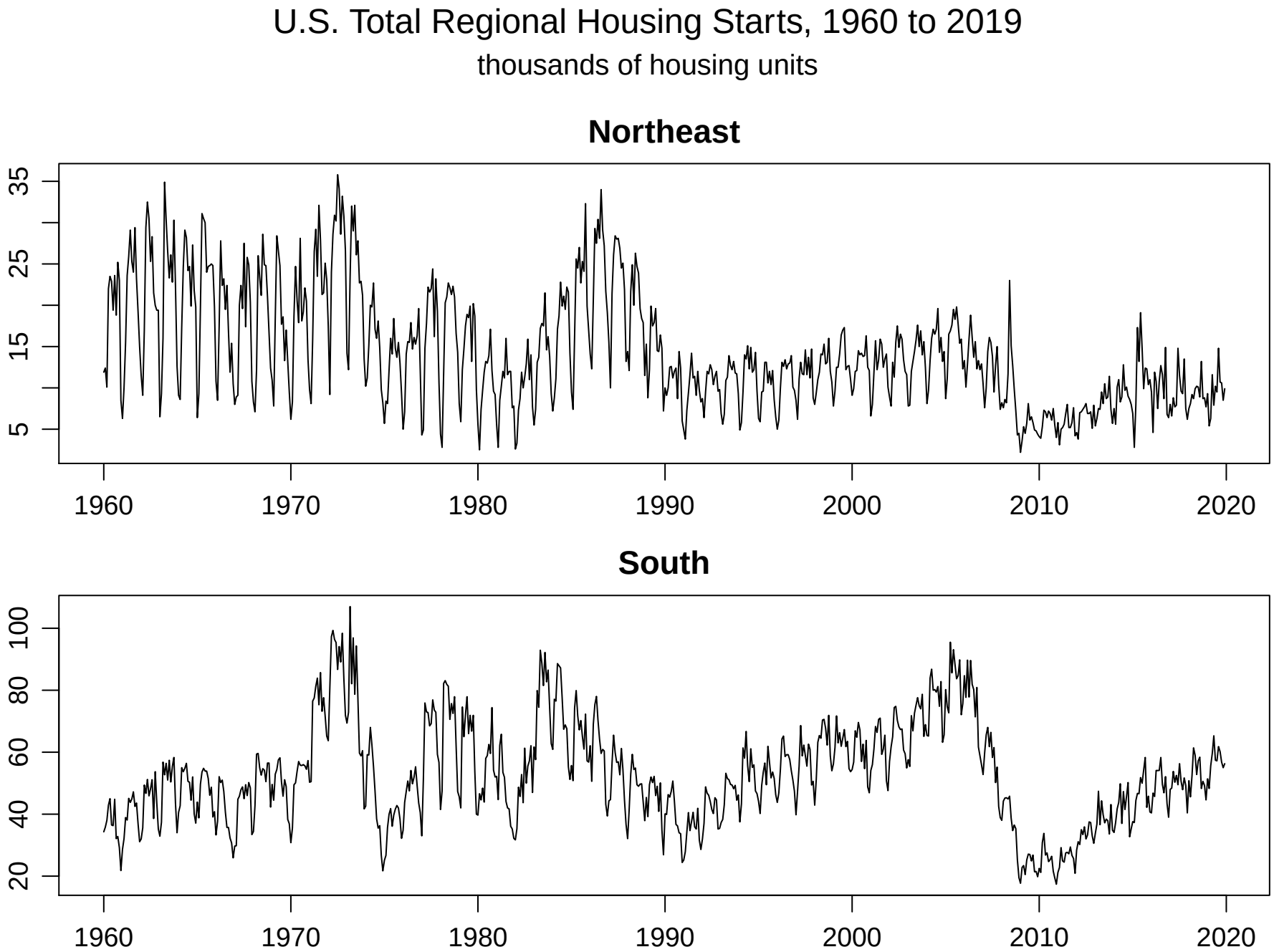
Disclaimer: Any views expressed here are those of the author and not those of the U.S. Census Bureau.

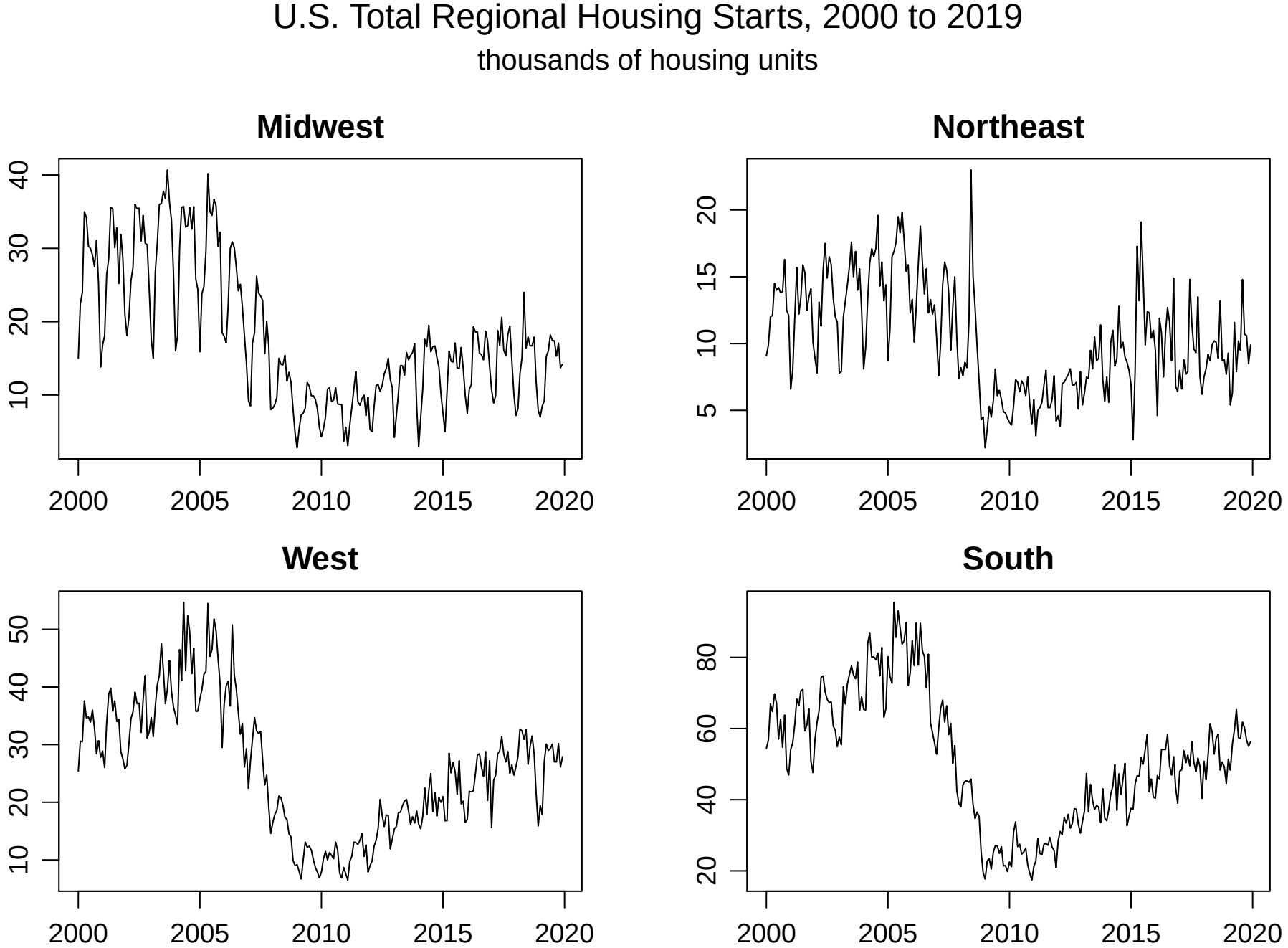
Background references for this talk

Trimbur, T.M. and Bell, W.R. (2012), "Seasonal Heteroskedasticity in Time Series Data: Modeling, Estimation, and Testing," Chapter 2 in Economic Time Series: Modeling and Seasonality. eds: W. Bell, S. Holan, and T. McElroy, Chapman and Hall.

Pang, O., Bell, W.R., Monsell, B.C. (2022), "Accommodating Weather Effects in Seasonal Adjustment: A Look into Adding Weather Regressors for Regional Construction Series," CSRM Research Report Series, Statistics #2022-01, U.S. Census Bureau, available at https://www.census.gov/library/working-papers/2022/adrm/RRS2022-01.html.


U.S. Total Regional Housing Starts, 1960 to 2019
thousands of housing units
Midwest
10
30
50
1960
1970
1980
1990
2000
2010
2020
West
10
20
30
40
50
1960
1970
1980
1990
2000
2010
2020


U.S. Total Regional Housing Starts, 1960 to 2019
thousands of housing units
Northeast
5
15
25
35
1960
1970
1980
1990
2000
2010
2020
South
20
40
60
80
100
1960
1970
1980
1990
2000
2010
2020


U.S. Total Regional Housing Starts, 2000 to 2019
thousands of housing units
Midwest
10
20
30
40
2000
2005
2010
2015
2020
Northeast
5
10
15
20
2000
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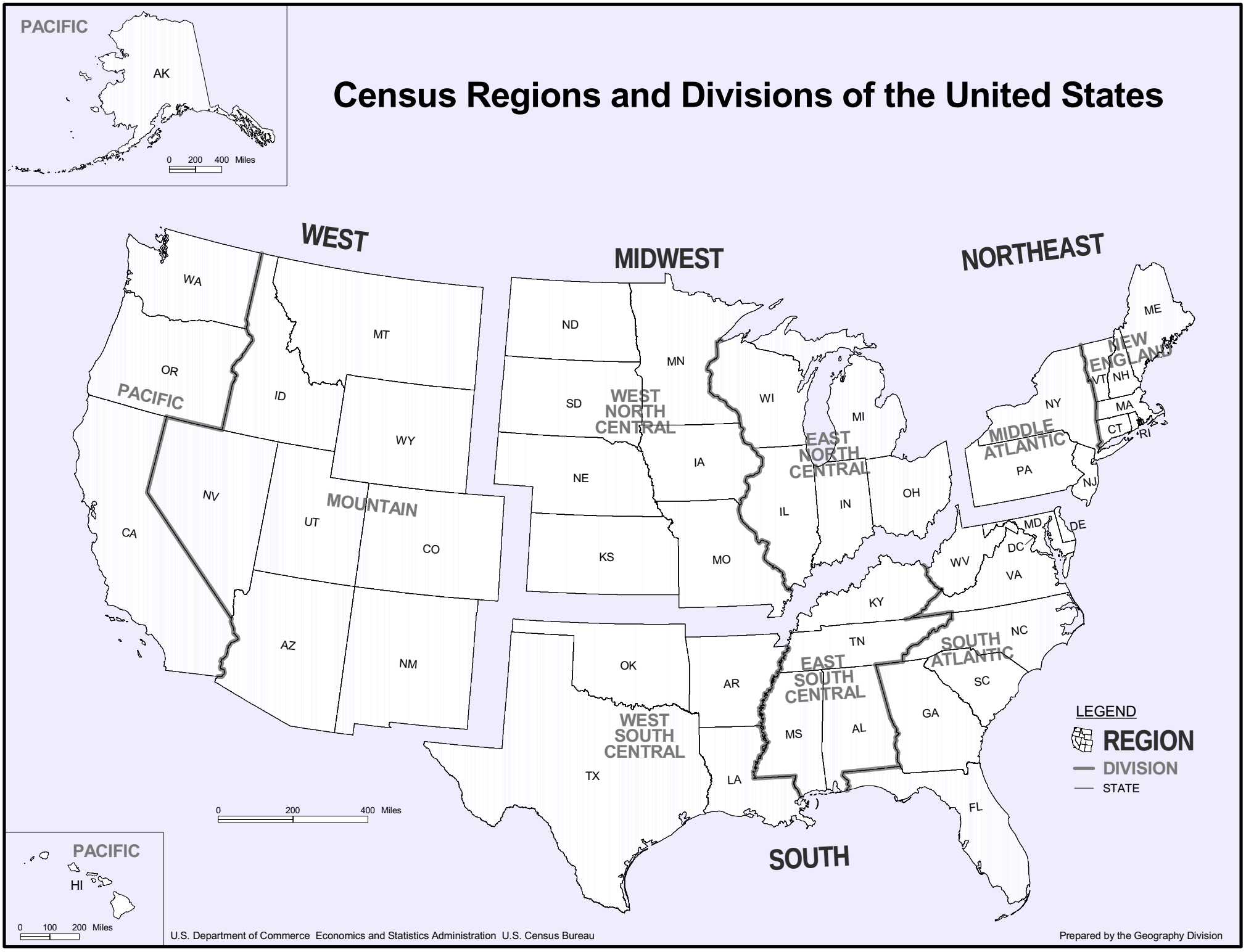
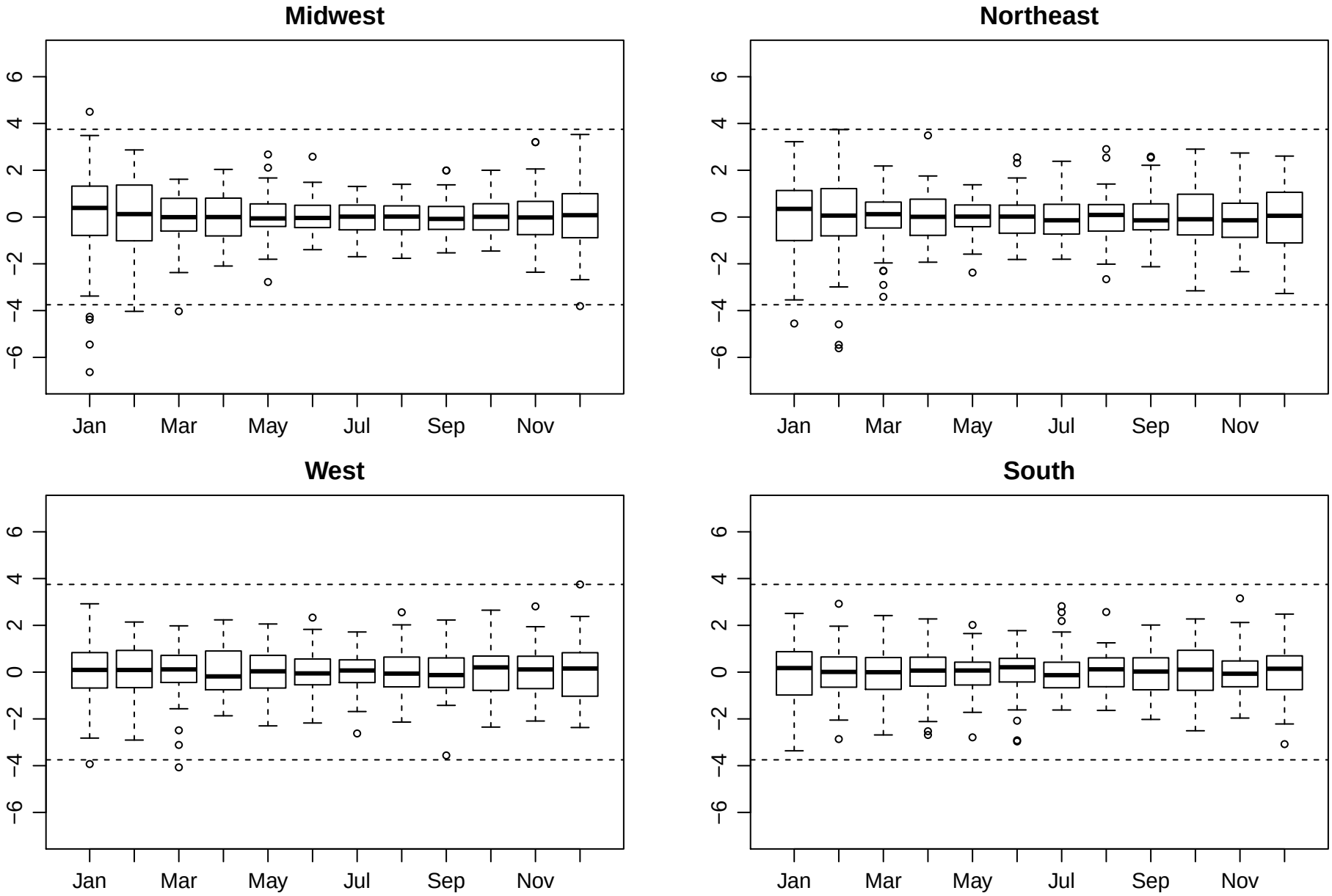

PACIFIC
AK
0 200 400 Miles
Census Regions and Divisions of the United States
WEST
MIDWEST
NORTHEAST
SOUTH
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
PACIFIC
MOUNTAIN
ND
SD
NE
KS
MN
IA
MO
WI
IL
MI
IN
OH
WEST NORTH CENTRAL
EAST NORTH CENTRAL
ME
VT
NH
NY
MA
CT
RI
PA
NJ
NEW ENGLAND
MIDDLE ATLANTIC
MD
DE
DC
WV
VA
KY
TN
NC
SC
GA
FL
AL
MS
LA
TX
OK
AR
SOUTH ATLANTIC
EAST SOUTH CENTRAL
WEST SOUTH CENTRAL
0 200 400 Miles
PACIFIC
HI
0 100 200 Miles
LEGEND
REGION
DIVISION
STATE
U.S. Department of Commerce Economics and Statistics Administration U.S. Census Bureau
Prepared by the Geography Division

U.S. Total Regional Housing Starts, 1960 to 2019

Boxplots of AO t−statistics by month



General Questions

1. To what extent can the higher variability and potential outliers, particularly in winter months, be explained by time series models as due to severe weather effects?

2. How does modeling, and possibly adjusting for, weather effects affect seasonal adjustments?

Focus will be on results for the Midwest and Northeast regions.

Previous Research on Weather Effects on Housing Starts

1987 Goodman, John L. "Housing and the Weather," *Journal of the American Real Estate and Urban Economics Association*.

1989 Cammarota, Mark T. "The Impact of Unseasonable Weather on Housing Starts," *Journal of the American Real Estate and Urban Economics Association*.

1996 Coulson, Edward N. and Richard, Christian "The Dynamic Impact of Unseasonable Weather on Construction Activity," *Real Estate Economics*.

1999 Fergus, James T. "Where, When, and by how Much Does Abnormal Weather Affect Housing Construction?" *Journal of Real Estate Finance and Economics*.

General findings: some evidence of effects of unseasonal weather, especially in winter and for the colder regions.

Other Research on Weather Effects on Economic Time Series

- Ewing et al. (2007): effects of severe wind events on housing price indices
- Bertrand et al. (2015): effects of unusual temperatures on apparel sales in France
- Appelqvist et al. (2016): weather effects on sporting goods sales in Finland and Switzerland
- Arunraj and Ahrens (2016): weather effects on food and fashion retail sales in Germany

Other Research on Weather Effects on Economic Time Series

- Sandqvist and Siliverstovs (2018): weather effects on Swiss retail sales
- Steinker et al. (2017): weather effects on e-commerce fashion retail sales
- Moon et al. (2018): weather events and grocery shopping
- Boldin and Wright (2015): adjusting employment time series for seasonal and weather effects
- Schreiber (2017): seasonal and weather adjustment of German economic series

RegARIMA modeling of weather effects

(Pang, Bell, and Monsell, CSRM Research Report #2022-01)

$$y_t = \mathbf{x}_t'\boldsymbol{\beta} + z_t$$

- y_t = log(housing starts for month t / length of month t)
- $\mathbf{x}_t$ contains TD and regional weather regressors (plus an AO for June 2008 in Northeast)
- $(1 - B)(1 - B^{12})z_t = (1 - \theta_1 B)(1 - \theta_{12}B^{12})a_t$ (airline model)

Weather Data (1)

- Weather data sourced from NOAA website
- Weather stations, 16 weather variables considered

Temperature	Precipitation	Snow
#(days min $\leq$ 0 F) (DT00)	#(days $\geq$ 0.1 in) (DP01)	
#(days min $\leq$ 32 F) (DT32)	#(days $\geq$ 0.5 in) (DP05)	
#(days max $\leq$ 32 F) (DX32)	#(days $\geq$ 1.0 in) (DP10)	
#(days max $\geq$ 90 F) (DT90)		
Max daily (EMXT)	Max daily (EMXP)	Max depth (MXSD)
Min daily (EMNT)		
Mean max (MMXT)		
Mean min (MMNT)		
Mean (MNTM)		
	Total (TPCP)	Total (TSNW)

United States Census Bureau

Regional weather effect regressors selected
(best 3 variable models)

Midwest

DX32: # days with high temperature $< 32^{\circ}F$ $(t = -6.0)$

MXSD: maximum snow depth $(t = -4.5)$

DP01: # days with precipitation > 0.1 inch $(t = -4.4)$

Northeast

DX32: # days with high temperature $< 32^{\circ}F$ $(t = -8.0)$

MXSD: maximum snow depth $(t = -1.1)$

TPCP: total precipitation $(t = -2.8)$

AO outliers without and with weather effects in models

Midwest (9 AOs without, 4 with)

without	Mar 1960	Jan 1963	Jan 1977	Jan 1979	Feb 1979
with	–	–	–	–	–
without	Feb 1982	Jan 2011	Jan 2013	Jan 2014	
with	Feb 1982	Jan 2011	Jan 2013	Jan 2014	

Northeast (7 AOs without, 3 with)

without	Jan 1978	Feb 1978	Feb 1980	Feb 1981	Jan 1982
with	–	Feb 1978	Feb 1980	Feb 1981	–
without	Jan 2009	Feb 2015			
with	–	–			

New results on modeling seasonal heteroskedasticity in U.S. regional housing starts

Airline + *month specific seasonal noise* RegComponent model:

$$y_t = \mathbf{x}_t'\boldsymbol{\beta} + z_t + \sum_{i \in \mathcal{S}} h_{it}\varepsilon_{it}$$

- y_t, z_t, and $\mathbf{x}_t$ as before (with no weather regressors in $\mathbf{x}_t$)
- $h_{it} = 1$ for $t \sim$ calendar month i for $i = 1, 2, \ldots, 12$
- $\varepsilon_{it} \sim i.i.d.\ N(0, \sigma_i^2)$
- $\mathcal{S} \subseteq \{1, 2, \ldots, 12\}$

Algorithm to determine months with seasonal heteroskedasticity

Start with $\mathcal{S} = \{1, 2, \ldots, 12\}$

1. Fit airline + month specific seasonal noise model
2. Find month with the lowest estimated σ_i^2
3. Drop this month from the set $\mathcal{S}$
4. Repeat steps 1–3 until $\mathcal{S}$ is empty, then fit the model with no seasonal noise terms.
5. Compare the 13 fitted models using AIC or BIC.

Algorithm to determine months with seasonal heteroskedasticity

Midwest total housing starts, 1/1959 – 12/2019

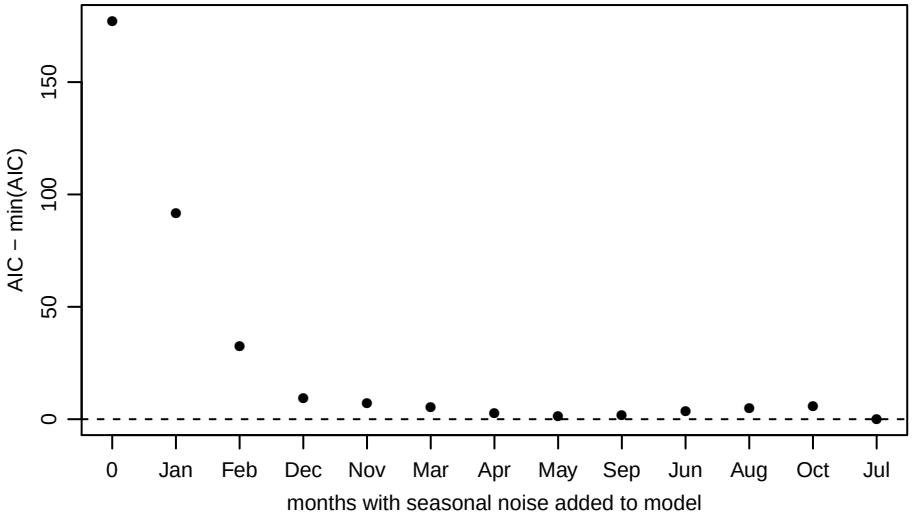
	# months with seasonal noise					
	12	11	10	9	8	7
month to drop	Jul	Oct	Aug	Jun	Sep	May
$100 \times \hat{\sigma}_\epsilon^2$	...	...	...	.12	.26	.39

	# months with seasonal noise					
	6	5	4	3	2	1
month to drop	Apr	Mar	Nov	Dec	Feb	Jan
$100 \times \hat{\sigma}_\epsilon^2$	.55	.55	.56	1.82	4.08	6.04

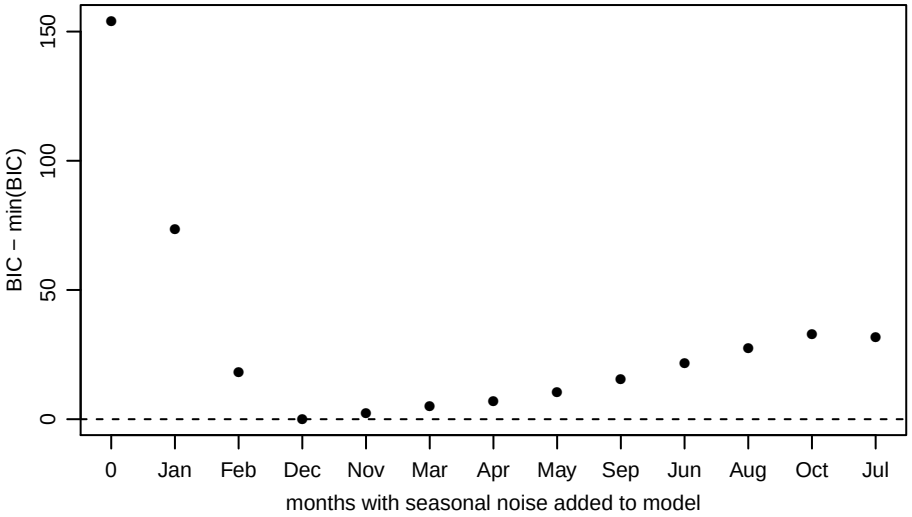
U.S. Total Regional Housing Starts, 1959 to 2019

AIC and BIC values (differences from the minima) as months with seasonal noise are added to the models

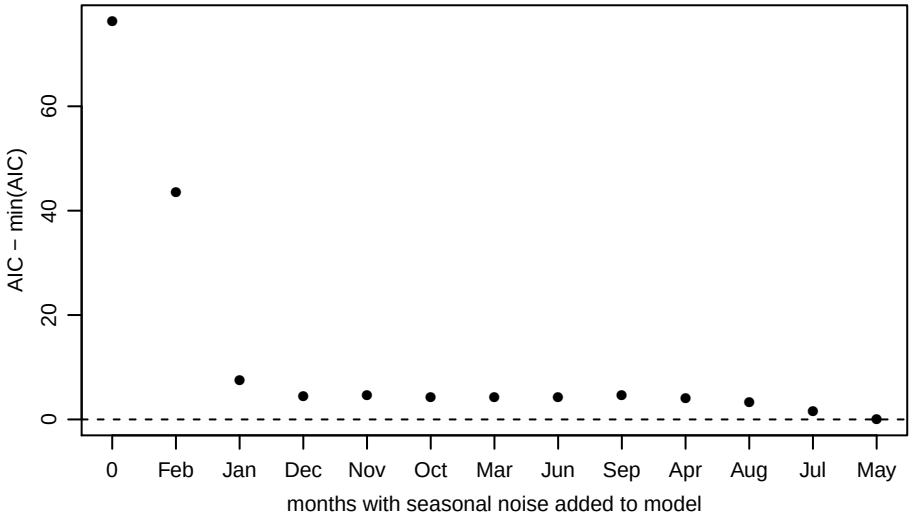
Midwest AICs



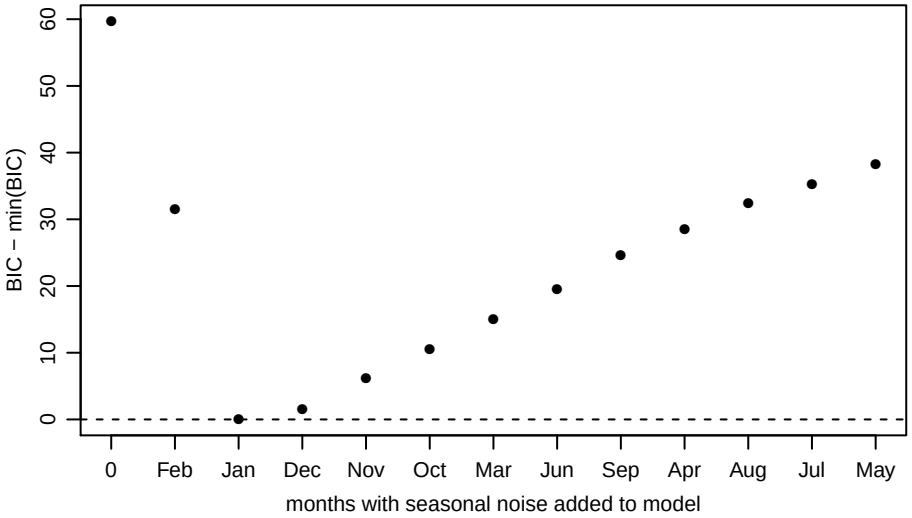
Midwest BICs



Northeast AICs



Northeast BICs



Remaining Questions

1. Do we need both weather effect regressors and seasonal noise in the models for Midwest and Northeast housing starts?

2. How does modeling, and possibly adjusting for, weather effects affect the resulting seasonal adjustments and trend estimates?

Estimating models with weather effects and seasonal heteroscedasticity

Midwest

weather effects?	seasonal heterosc?	t-statistics $\hat{\beta}_{DX32}$	$\hat{\beta}_{MXSD}$	$\hat{\beta}_{DP01}$	seasonal variances $\hat{\sigma}^2_{Jan}$	$\hat{\sigma}^2_{Feb}$	$\hat{\sigma}^2_{Dec}$
yes	no	−6.0	−4.5	−4.4	–	–	–
no	yes	–	–	–	.075	.042	.017
yes	yes	−4.5	−3.6	−5.1	.052	.025	.008

Estimating models with weather effects and seasonal heteroscedasticity

Northeast

weather effects?	seasonal heterosc?	*t*-statistics $\hat{\beta}_{DX32}$	$\hat{\beta}_{MXSD}$	$\hat{\beta}_{TPCP}$	seasonal variances $\hat{\sigma}^2_{Jan}$	$\hat{\sigma}^2_{Feb}$	$\hat{\sigma}^2_{Dec}$
yes	no	−8.0	−1.1	−2.8	–	–	–
no	yes	–	–	–	.050	.062	.013
yes	yes	−6.0	−2.0	−3.1	.026	.052	.010

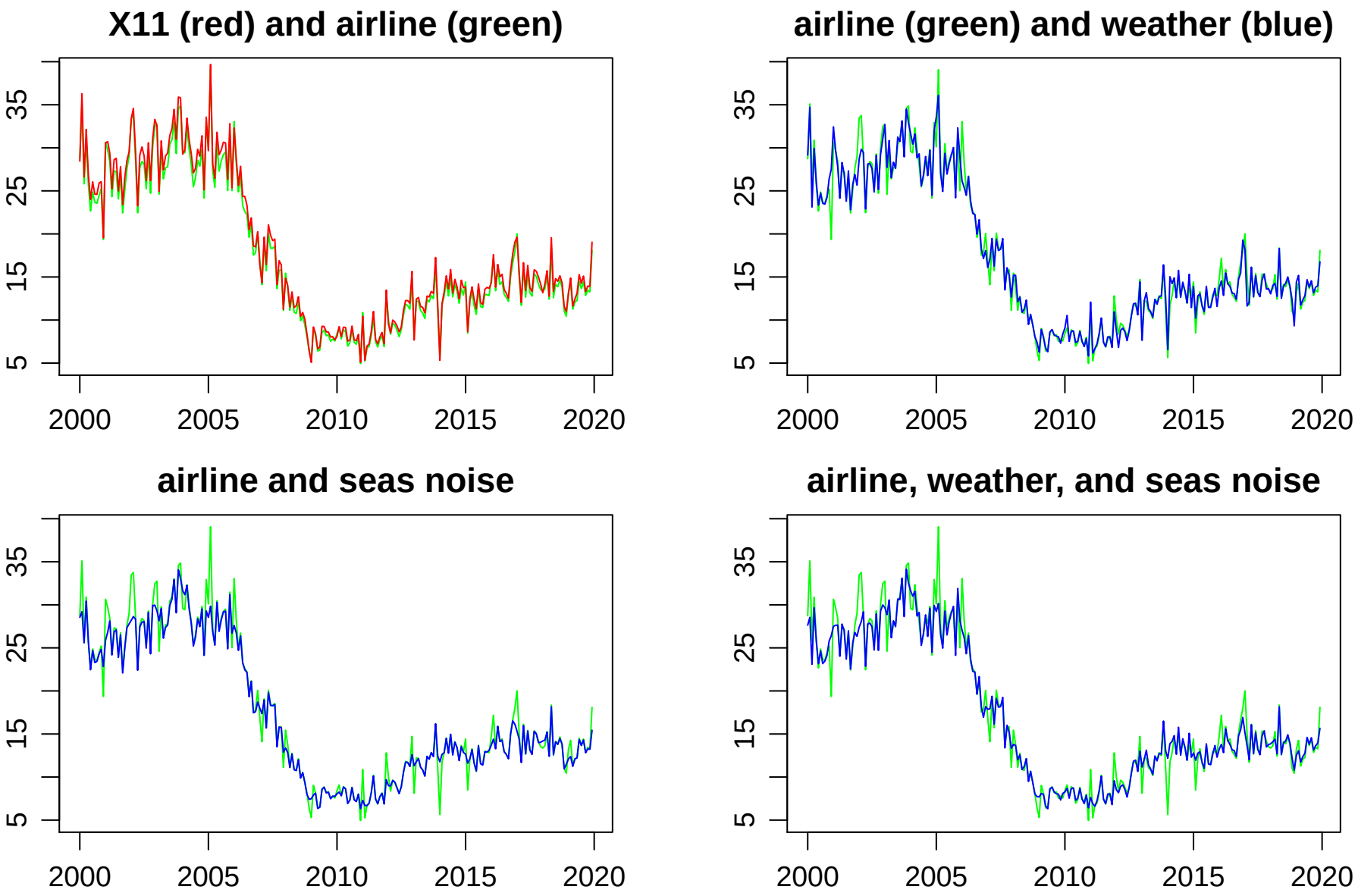
Comparing the models

AIC and BIC differences from the model with neither weather effects nor seasonal heteroskedasticity

weather effects?	seasonal heterosc?	Midwest ΔAIC	Midwest ΔBIC	Northeast ΔAIC	Northeast ΔBIC
no	no	–	–	–	–
yes	no	-143	-129	-83	-70
no	yes	-172	-159	-78	-64
yes	yes	-264	-237	-138	-111

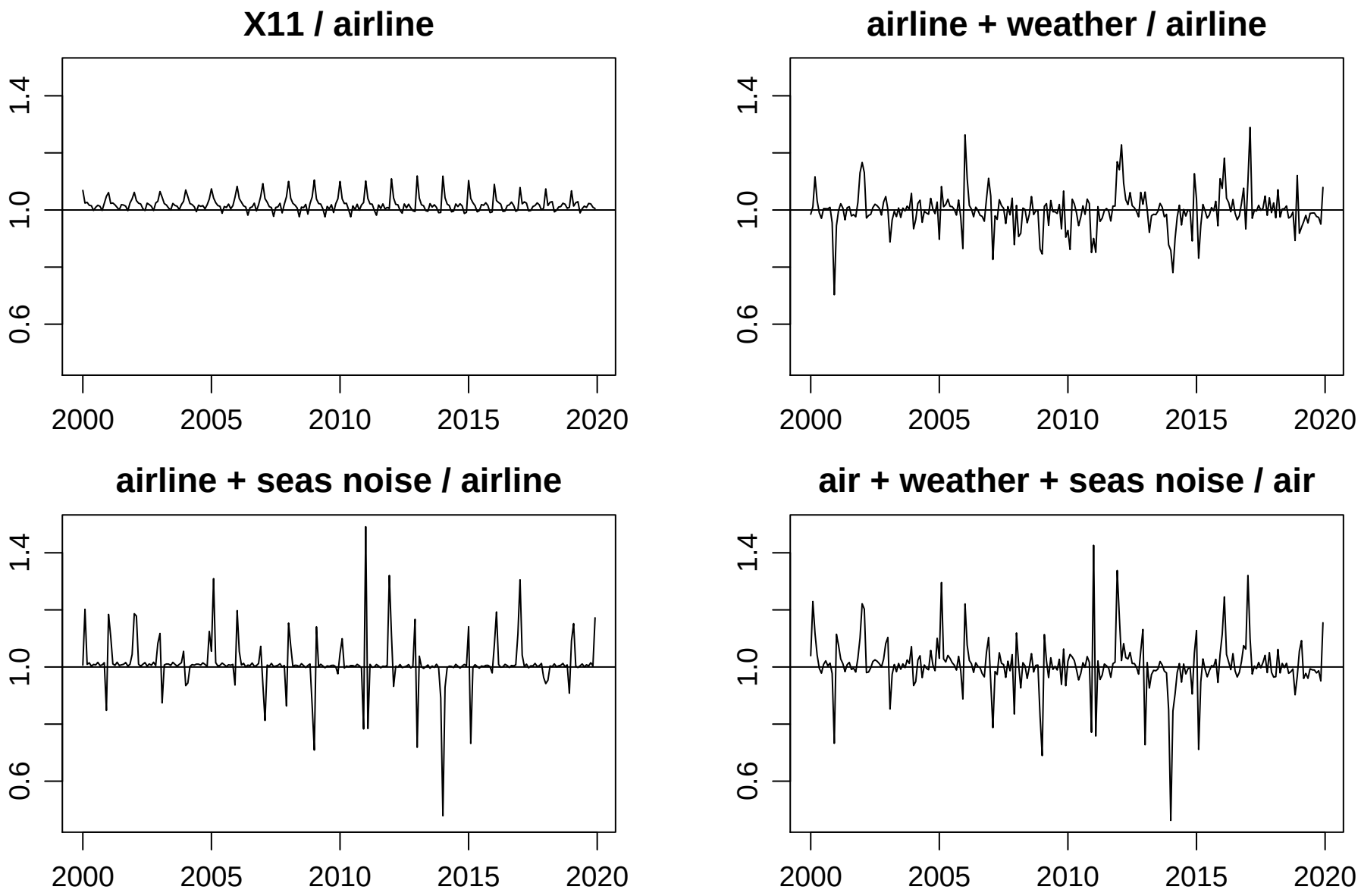
Midwest Total Housing Starts, 2000 to 2019

Adjustments for seasonality, weather effects, and seasonal noise



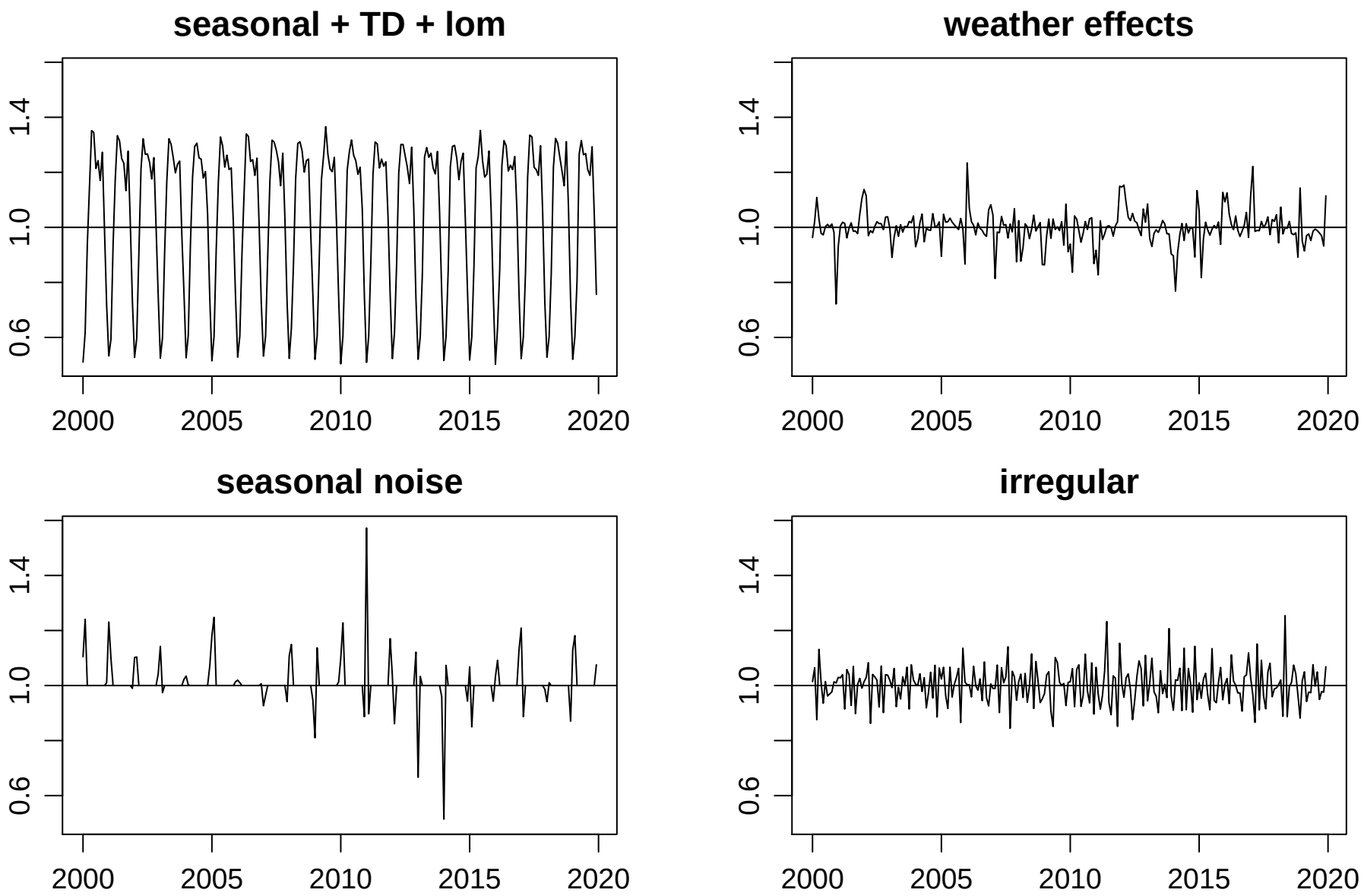
Midwest Total Housing Starts, 2000 to 2019

Ratios of adjustment factors (bias corrected for model−based)



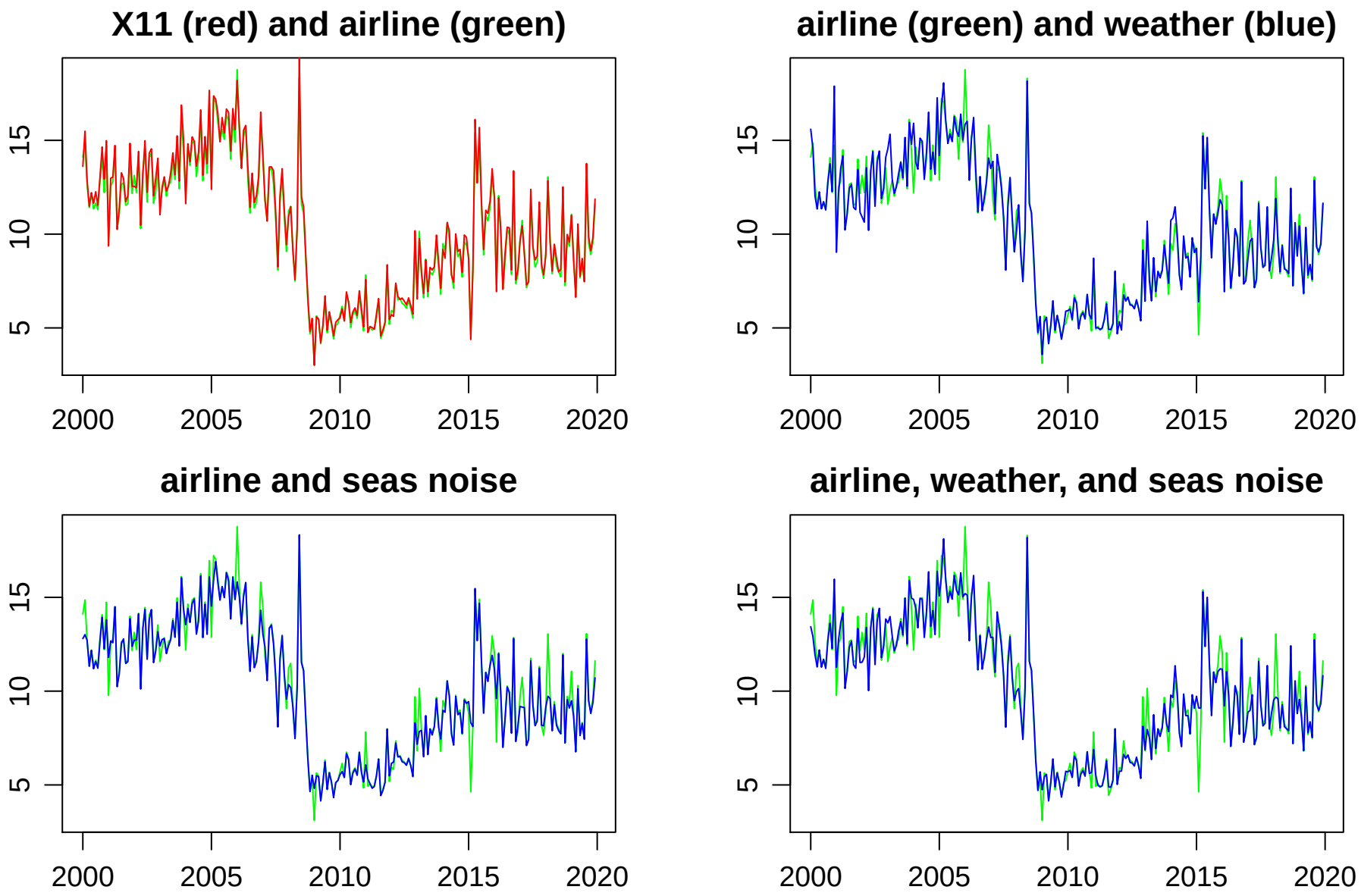
Midwest Total Housing Starts, 2000 to 2019

Multiplicative components of seasonal and weather adjustment



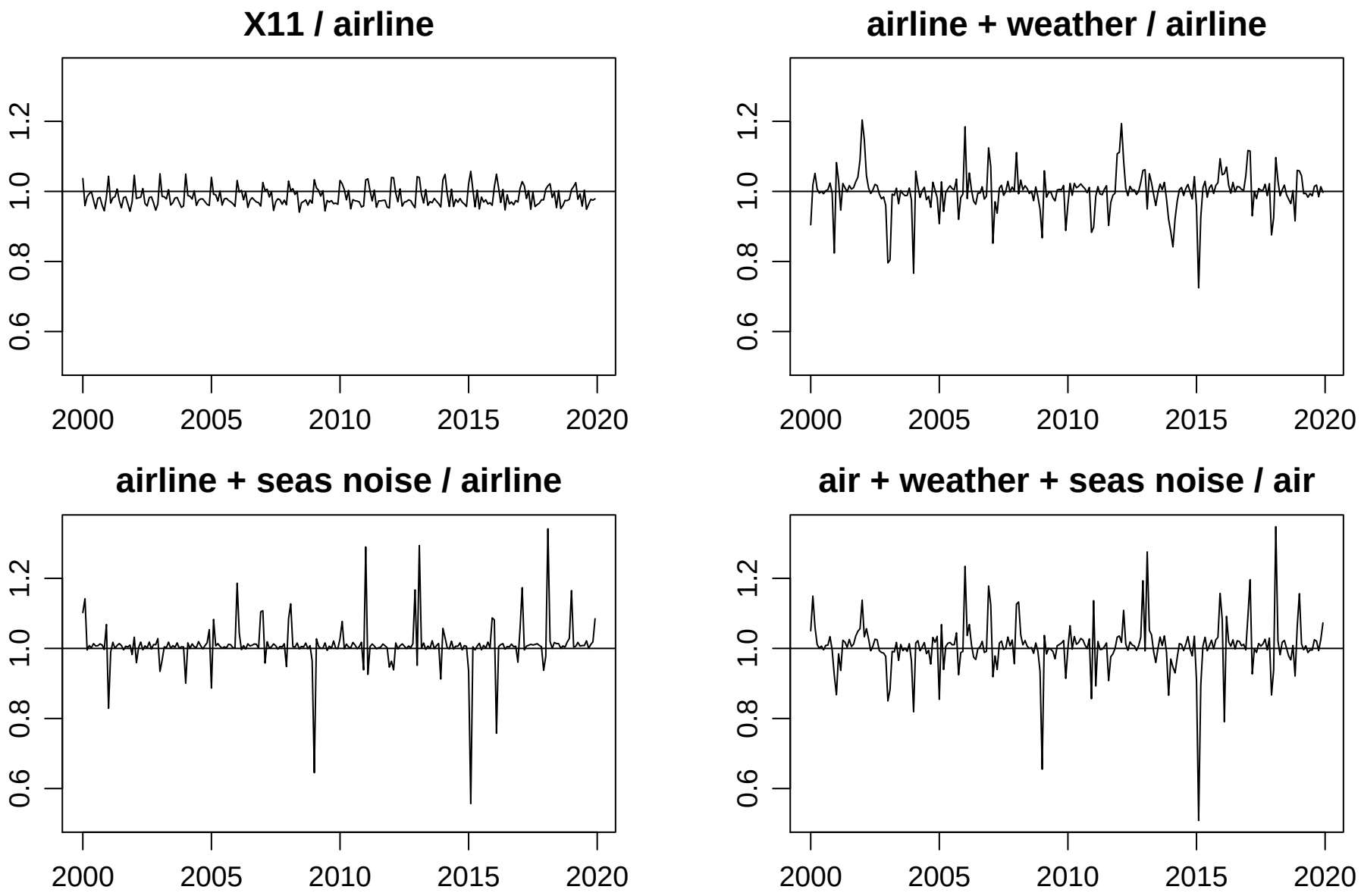
Northeast Total Housing Starts, 2000 to 2019

Adjustments for seasonality, weather effects, and seasonal noise



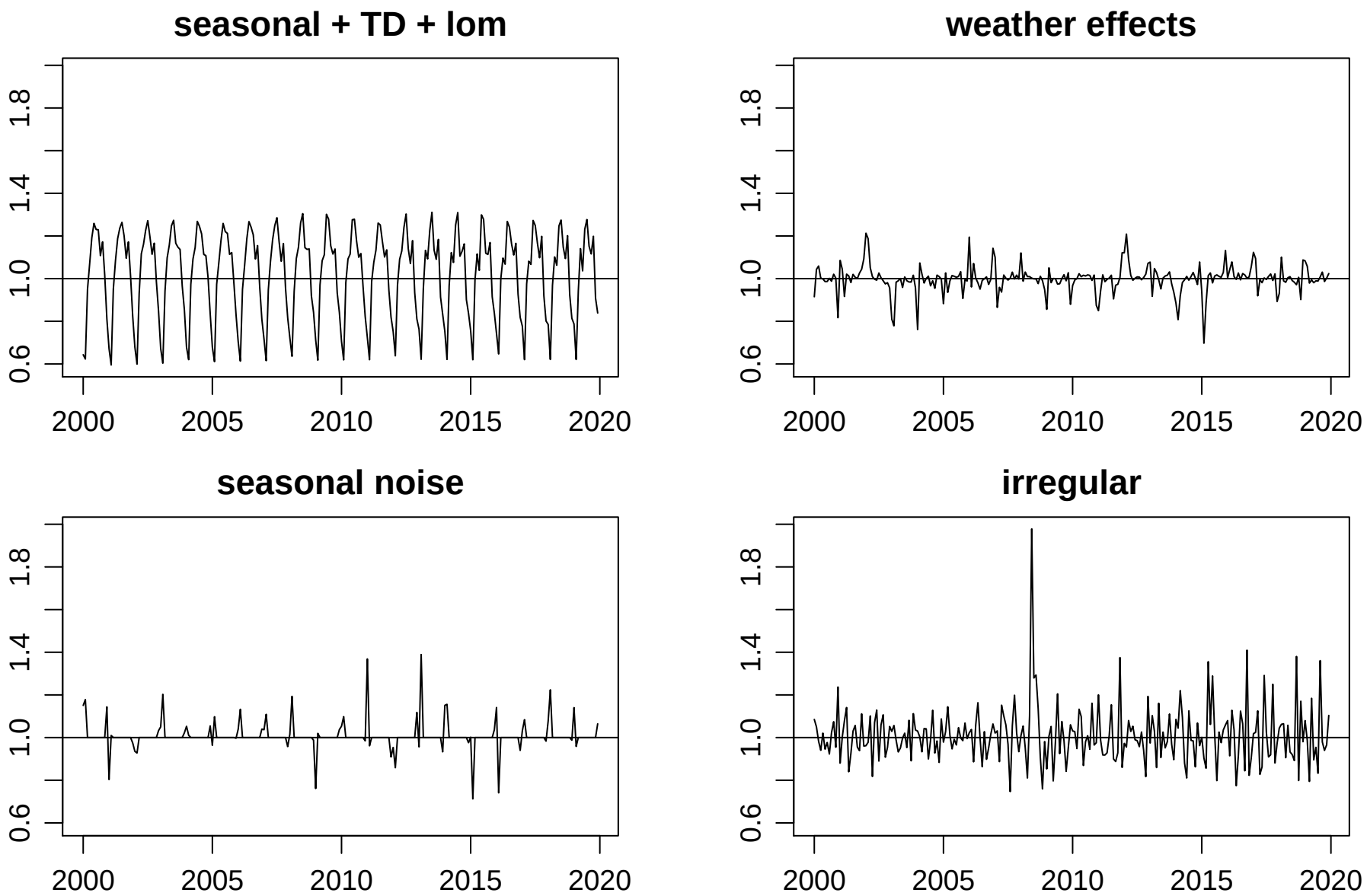
Northeast Total Housing Starts, 2000 to 2019

Ratios of adjustment factors



Northeast Total Housing Starts, 2000 to 2019

Multiplicative components of seasonal and weather adjustment



Conclusions

1. Both explicitly modeled weather effects and heteroskedastic seasonal noise were found to be very significant for modeling Midwest and Northeast housing starts.
    - Explicitly modeled weather effects explained some, not all, outliers
    - Seasonal noise reflected a larger amount of variation in housing starts than the modeled weather effects, especially for the Midwest.

Conclusions

2. Should we adjust for weather effects and/or seasonal noise?

   - Depends, in principle, on the objectives of the data user
   - The examples illustrate that adjusting for weather effects and seasonal noise can have substantial effects for some time series. In the housing starts example, these effects were more consequential than a decision about choosing between X-11 and model-based adjustment.

Things not covered in this presentation:

- Results for the South and West regions
- Results for other types of structure (5+, etc.)
- Results for Building Permits – strong seasonal noise for Midwest and Northeast
- Allowance for sampling error components in the models