Some Historical Perspectives on Seasonal Adjustment

William R. Bell, U.S. Census Bureau

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Outline

1. Early history of seasonal adjustment
2. Use of electronic computers for seasonal adjustment
3. Relevant developments in time series modeling
4. Combining time series modeling and traditional (X-11) seasonal adjustment
5. Model-based seasonal adjustment
6. Comparing X-11 and model-based seasonal adjustment
7. Some current issues and possible future directions for seasonal adjustment

1. Early history of seasonal adjustment

Very early history

- Nerlove, Grether, and Carvalho (1979) – idea of time series coming from unobserved components came from astronomy and meteorology and became popular in economics in England, 1825-1875.
- Discuss seasonal adjustment work of Dutch meteorologist Buys-Ballot (1847).

Note: For historical reference citations in what follows, and for additional discussion, see Bell and Hillmer (1984, "Issues Involved with the Seasonal Adjustment of Economic Time Series," (with discussion), Journal of Business and Economic Statistics, pp. 291–349).

Fundamental paper: Persons (1919)

Viewed economic time series as composed of:

- long-time tendency or secular trend
- wave-like or cyclical movements
- seasonal movements
- residual variation

Persons may have been the first to propose a general method that could adequately decompose an economic time series into the above four components

1920s and 1930s – explosion of interest in seasonal adjustment

Important concepts that became fixed:

1. seasonality is often multiplicative – to seasonally adjust, divide data by seasonal factors
2. seasonality can change over time – estimate seasonal factors using moving averages
3. must account for trends and cycles when estimating the seasonal component – iterate between detrending and estimating the seasonal
4. cannot describe trends and cycles by explicit formulas – estimate trends by moving averages
5. need to deal with extreme observations – used moving medians or trimmed means instead of moving averages

Outcome: Ratio-to-moving average approach, with some adjustment for extreme values

2. Use of electronic computers for seasonal adjustment

Primary motivation: to increase the number of seasonally adjusted series

1954 Census Bureau – Julius Shiskin and colleagues develop an approach (Method I) for doing seasonal adjustments on the Univac 1

1955 Method II, X-1 variant

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1965 Method II, X-11 variant

Impacts of doing seasonal adjustment on electronic computers

- reduced costs so many more series could be seasonally adjusted
- calculations required could be more complicated
- time spent determining how best to reduce a given series was reduced
  - methods had to automatically deal with things previously left to professional judgment
- automatic nature lent an air of objectivity to the process
  - contrast to some early methods that used free-hand smoothing
- regression used to estimate and adjust for trading-day effects (Young 1965)

Early developments:

- autoregressive models (Yule 1927)
- moving average models (Slutsky 1937, Wold 1938)
- AR models with seasonal lags (Whittle 1952,1953a,1954a)
- regression models with time series errors (Whittle 1954b,Durbin 1960a)
- model estimation (Whittle 1953a,b,1954b; Durbin 1959,1960a,b; Walker 1961,1962)

Book by Box and Jenkins (1970): *Time Series Analysis: Forecasting and Control*

Developed a systematic approach to seasonal ARIMA modeling

Airline model: $(1-B)(1-B^{12})z_t = (1-\theta_1 B)(1-\theta_{12} B^{12})a_t$

- nonseasonal differencing for detrending
- seasonal differencing to allow for changing seasonality
- book was followed by software development

4. Combining time series modeling and traditional (X-11) seasonal adjustment

- X-11-ARIMA (Dagum 1980)
  - ARIMA forecast extension to do linear filtering at ends of series
  - log-additive adjustment
- RegARIMA modeling for estimation and inference about calendar effects (Bell and Hillmer 1983)
- Use of time series outlier detection for Additive Outliers and Level Shifts (Chang 1982, Bell 1983, Tsay 1986)
- X-12-ARIMA (Findley et al. 1998)

5. Model-based seasonal adjustment

- Attempts based on regression (1922-1972) had little impact
- Canonical ARIMA model-based adjustment (now in use)
  - Box, Hillmer, and Tiao (1978); Hillmer and Tiao (1982)
  - Burman (1980)
  - Software developed
    - Gomez and Maravall (1997) – TRAMO/SEATS
    - X-13 (U.S. Census Bureau 2012) – combines features of X-12-ARIMA and TRAMO/SEATS
- Approaches based on directly specifying ARIMA component models
  - BAYSEA (Akaike 1980)
  - Structural models – Harvey (1989), Durbin and Koopman (2001)

6. Comparing X-11 and model-based seasonal adjustment

Cleveland and Tiao (1976) compared, for trend and seasonal filters:

- X-11 filter weights w_j^{X11} (for derivation, see Wallis 1974) obtained with "default" choices of the MAs (3×5 seasonal MA and 13-term Henderson trend MA), and

- filter weights w_j^{MB} from signal extraction with component models of a given form (see below).

They determined the component model parameter values to

$$\min \sum_j (w_j^{X11} - w_j^{MB})^2$$

summing over the values of j for which the X-11 weights were appreciable ($j = -42$ to 42).

Cleveland and Tiao determined the following 3-component model ($Y_t = S_t + T_t + I_t$) for approximating both the X-11 seasonal and trend filters:

$$(1 - B^{12})S_t = (1 + .49B^{12} - .49B^{24})b_t \qquad \sigma_b^2/\sigma_c^2 = 1.3$$

$$(1 - B)^2 T_t = (1 + .64B + .83B^2)c_t$$

$$I_t = \text{white noise} \qquad \sigma_I^2/\sigma_c^2 = 14.4.$$

The implied model for Y_t is that $(1 - B)(1 - B^{12})Y_t$ follows an MA(25) model.

Extensions to the work of Cleveland and Tiao

- Burridge and Wallis (1984) developed
  - models to approximate **symmetric and asymmetric X-11 seasonal adjustment filters**, and
  - model-based approximations to X-11 filters using the **optional** 3×3 **and** 3×9 **seasonal MAs**.
- Chu (2000) used higher order models and so obtained better approximations to various X-11 filters.
- Planas and Depoutot (2002) restricted consideration to **canonical decomposition of the airline model for approximating the X-11 filters**.
- Depoutot and Planas (1998) considered **picking an X-11 filter** (through choice of seasonal and trend MAs) **to approximate a given airline model-based adjustment filter** obtained from the canonical decomposition.

Statistical (MSE) comparisons of X-11 and model-based seasonal adjustments (Chu, Tiao, and Bell 2012)

1. Assume Y_t follows the airline model and the true S_t and N_t come from the canonical decomposition of this model.

2. Let N_t^{X11} be the X-11 seasonal adjustment for any given choice of

   seasonal MA: $(3 \times 1,\ 3 \times 3,\ 3 \times 5,\ 3 \times 9,$ or $3 \times 15)$

   Henderson trend MA: (9, 13, 17, or 23-term).

   Compute $E[(N_t^{X11} - N_t)^2]$ for all 20 of these combinations and let $\hat{N}_t^{X11}$ be the X-11 estimate among these with the lowest MSE.

3. Let $\hat{N}_t$ be the MMSE linear predictor of N_t from the model. Examine the increase in MSE from using $\hat{N}_t^{X11}$ compared to $\hat{N}_t$ by

$$\text{X-11 MSE \% increase} = 100 \times \frac{E[(\hat{N}_t^{X11} - N_t)^2] - E[(\hat{N}_t - N_t)^2]}{E[(\hat{N}_t - N_t)^2]}.$$

Comparing MSEs for X-11 and Model-based Filters
Canonical decomposition of the airline model with $\theta_1 = .5$

	θ_{12}			
	.2	.5	.8	.9
Best X-11 seasonal MA	3×1	3×5	3×15	3×15
MSE % increase for X-11				
symmetric filter	14%	6%	10%	33%
concurrent filter	3%	1%	3%	9%

Summary of Conclusions from Chu, Tiao, and Bell

- Length of best X-11 seasonal MA increases with θ_{12}. X-12 automatic filter selection sometimes picks shorter seasonal MAs than the best (assessed in a small simulation study).
- The best X-11 filters generally do pretty well for estimating the canonical decomposition, especially for concurrent adjustment or (Bell, Chu, and Tiao 2012) finite sample adjustments with a series that is not long.
- Lone exception where best X-11 filter does poorly: seasonal adjustment in the middle of a very long series when θ_{12} is large (.9).
- Other X-11 filters with a seasonal MA close to the best choice (for example, 3×3 when $\theta_{12} = .5$) have only slightly larger MSEs. X-11 filters far from the best can have larger MSE increases.

7. Some current issues and possible future directions for seasonal adjustment

Seasonally adjusting time series with sampling error

$$Y_t = S_t + T_t + I_t \quad \rightarrow \quad Y_t = S_t + T_t + I_t + e_t$$

$$e_t = \text{ sampling error in } Y_t$$

- Question: Is seasonal adjustment estimating

$$N_t = T_t + I_t$$

$$\text{or} \quad A_t \quad = \quad Y_t - S_t = T_t + I_t + e_t?$$

- For more on this topic, see next talk by Dick Tiller.

Variances for seasonal adjustment

- For model-based adjustment – falls out of the calculations
- For X-11, variance approximations were given by
  - Pfeffermann (1994); Scott, Pfeffermann, and Sverchkov (2012)
  - Bell and Kramer (1999)
- For "exact" MSEs of X-11 adjustments, use the approach of Bell, Chu, and Tiao (2012)
- Questions to be answered:
  - Is seasonal adjustment estimating N_t or $Y_t - S_t = N_t + e_t$?
  - How to present the results, which produce a different variance for every time point.

Modeling and adjusting for weather effects or seasonal heteroskedasticity

- Boldin and Wright (2015) – model effects of unusual weather on employment data
- Trimbur and Bell (2012) – model seasonal heteroskedasticity (higher variance in winter months) for U.S. regional housing starts and building permits
- Concurrent session I: Talks by Osbert Pang and Thomas Trimbur

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