Time Series Methods for Official Statistics

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Content

- Components of Time Series
- Seasonal Adjustment
  - Virtual Analyst
- Raking / Reconciliation
- Benchmarking
- Linking
- Interpolation
Flow Series

Original Series
TG170 - Department Series Sales - Canada

Stock Series

Original Series
Employment - Men 20 to 64 - Canada
Components of Time Series

- The most frequent components are:
  - the trend-cycle component
  - the seasonal component ("seasonality")
  - the trading-day component (week-day effect)
  - the Easter effect (Moving Holiday component)
  - the irregular component (the "irregular")

Trend-Cycle

Interpretation: Fundamental movement of the series, reflecting the prevailing economic conditions.
Seasonality

- Intra-year (monthly, quarterly) fluctuations which repeat more or less regularly from year to year.

**Original Series**

TG:00 - Department Store Sales - Canada

**Seasonal Factors**

TG:00 - Department Store Sales - Canada
Seasonality

Trading-Day

- Variation due to the changing number of times each day of the week occurs in a month.
- It is present when the activity varies with the days of the week.
- Trading-day variations imply the existence of an underlying *daily pattern of activity* defined over the week.
- The daily pattern states the relative importance of the days in the week.
Trading-Day

Trading Day Factors

Trading-day factor: includes day of the week component and leap-year effect.

Easter effect

- The Easter effect is the variation due to the displacement from April to March of a volume of activity when Easter falls in March instead of the usual April occurrence.

- This effect illustrates the more general moving holiday effect. More example: Chinese New Year effect on travel series, ...
Easter effect

Holiday Factors
TG170 — Department Stores Sales — Canada

Irregular

- The irregular component comprises the residual, erratic fluctuations of the series, which cannot be attributed to the "systematic" components: the trend-cycle, the seasonal, the trading-day and the Easter component.

- Interpretation:
  - Unusual events: e.g. strikes, colder than normal weather.
  - Temporary changes for a short period: e.g. SARS effect in number of travelers to Canada.
  - X-12-ARIMA has an Outlier detection procedure and a sophisticated Regression module that helps identifying and dealing with unusual events.
The seasonally adjusted series (SA) is:
- the combination of the trend-cycle and the irregular components or equivalently
- raw series from which the seasonal, trading-day and the Easter components have been removed.

The goal of seasonal adjustments is to:
- Remove the systematic intra-annual fluctuations to reveal the underlying trend-cyclical movements and special events.
Why Seasonally Adjust?

Why do seasonal adjustments?
- **Month-to-month** comparisons (on original series):
  - Dominance of seasonality.
  - Almost no information about the trend movement.

- **Same-month** comparisons (on original series):
  - Seasonality removed but calendar effect still there.
  - Lack timeliness.

Seasonal Adjustment

- X-11 Variant of Census Method II Seasonal Adjustment Program (Shiskin et al., 1967)
  - Method 1 (50-54): Moving averages
  - Method 2 (57): Iterations, treatment of extreme values, computer
  - X3, X9, X10, X11: Moving average weights improvement
  - X11: Regression techniques to estimate and correct for calendar (TD) effect

  - Use of ARIMA forecasts result in smaller revision in the SA series when more data are added at the end
  - Automatic ARIMA modelling
  - Tests for the presence of identifiable seasonality; moving seasonality; residual seasonality
  - Table of SA with revised annual totals
  - Estimation of Easter effect
  - Automatic removal of regression effects before ARIMA modelling
  - Automatic selection of seasonal moving average
  - Temporary and permanent prior adjustment

- X-12-ARIMA (Findley et al., 1998)
X-12-ARIMA, 1998, David Findley et al., USBC

- Major redesign of the computer program

RegARIMA Models
(Forecasts, Backcasts, Preadjustments)

Diagnostics and Graphs for modeling and model comparison

X-11 Seasonal Adjustment

Diagnostics and Graphs for Seasonal Adjustment

X-12-ARIMA

- RegARIMA modeling to pre-adjust and forecast:
  - Incorporate TD, Easter, Labor, Thanksgiving, AO, LS, TC, ramps, user-defined regressors
  - A new automatic outlier detection procedure for RegARIMA models

- New “X-11” options:
  - Pseudo-additive decomposition model
  - New moving averages

- New diagnostics
  - Spectrum estimates
  - Sliding spans
  - Revision history analysis

- Graph package (X-12-Graph)
- Windows Interface (WinX-12)
Implementation of X-12-ARIMA

- Build a first prototype system for time series processing that does seasonal adjustment with X-12-ARIMA for a given set of series;
- Deploy and adapt the prototype system to the various set of series among the Agency;
- Consider reviewing and updating the raking/reconciliation methodology and software;
- Consider reviewing and updating the benchmarking methodology and software;
- Standardize guidelines for seasonal adjustment, trend-cycle estimation, benchmarking and reconciliation for individual series and for the treatment of a set of series;

Time Series Processing

[Diagram showing data processing steps involving Expert system, X-12, pre, post, Bench, Variance, Graphs & Tools, and Trend.]
Virtual Analyst

- Given the diagnostics available in X-12-ARIMA, create a virtual analyst to help with the selection of the X-12-ARIMA seasonal adjustment options for production purposes.
- Refer to Guidelines from USBC and Eurostat (draft) and Stat Can (to be updated).

Flow Series (TD and E)

- The decomposition mode (multiplicative or additive) can use the results of the `transform` spec.
- The decision to seasonally adjust a series or not can use the result of the statistic M07.
- The ARIMA model can be automatically selected using the `pickmdl` spec.
- The significance of the Trading-day and Easter effects can be evaluated on the basis of the AIC-tests from the `regression` spec.
- Outliers can be automatically identified from the `outlier` spec.
- The length for the seasonal moving average and trend filter for the `x11` spec can be fixed on the basis of the I/C and I/S ratios (Ladiray and Quenneville, 2001).
Monthly Wholesale Trade Survey (MWTS)

MWTS publishes SA series according to 2 breakdowns:
- By industry (15 trade groups)
- By region (10 provinces, 3 territories)

Issue: how to calculate the Canada Wholesale Total so that both the 15 TG SA series and the 13 regions SA series add up to the Canada SA series?

Typical Case for Raking
Reconciliation/Raking

Step 1: Univariate Benchmarking

- In seasonal adjustment, it is often desired to benchmark to annual totals:
  - Annual SA totals = Annual raw or calendar-adjusted raw totals
  - Spec FORCE of X-12-ARIMA (V03)
  - Benchmarking to an external total
- Benchmarking is designed to preserve the movement in the SA series.
Benchmarking

- More details on benchmarking in a few slides …

Reconciliation/Raking

**Step 2: Multivariate Raking**

- When adjusting a set of series with additivity constraints, we rake the series while preserving the annual totals.

- For months in an incomplete year of data, the raking can simply be a proportional allocation of the difference between the 2 indirect totals.

- At this stage we found out that it was not necessary to preserve movement in the raking step when we were using the benchmarked series. This is where we were able to simplify the methodology and increase the computing speed significantly. (From 6 hours to 2 minutes!)
How is this done?
- Through a weighted regression model.
- With some data manipulation, this can be done easily with a PROC REG in SAS.
- Large Scale problems:
- Book:
- Software under development: Proc TSRAKING
Graphical example (one-way with annual constraints):

Wholesale Monthly Sales

Graphical example:
Difference between national level and sum of regions
Graphical example:

One region before and after raking

Reconciliation/Raking

Graphical example:

Thousands

Reconciliation/Raking
Reconciliation/Raking

Growth rate before and after raking

Benchmarking

- Benchmarking monthly series to make them agree with annual control totals or individual values at arbitrary points along the series is often performed on the series before (or after) seasonal adjustment.

- Statistics Canada has developed a SAS procedure, called PROC BENCHMARKING.
**Benchmarking Example**

![Graph showing benchmarking example](image)

**Benchmarking Issues**

1. Preserve movement in the sub-annual series as much as possible.
2. Account for the timeliness of annual benchmarks
BI-ratios with various methods

Annualized Growth Rates in 2005

<table>
<thead>
<tr>
<th>Series</th>
<th>3.04%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>N/A</td>
</tr>
<tr>
<td>BI-mean</td>
<td>5.37%</td>
</tr>
<tr>
<td>Pro-rating (not to be used)</td>
<td>4.23%</td>
</tr>
<tr>
<td>Regression with bias</td>
<td>3.91%</td>
</tr>
<tr>
<td>Regression without bias</td>
<td>3.29%</td>
</tr>
<tr>
<td>BI-last</td>
<td>3.04%</td>
</tr>
<tr>
<td>Denton</td>
<td>1.87%</td>
</tr>
</tbody>
</table>
Issues

- The amount of revision to the benchmarked series once the true value for 2005 becomes available is dictated by the accuracy of the forecast.

  1. How to best forecast (implicitly or explicitly) the missing benchmarks for the most recent periods when the only available information consists of the sub-annual series and the annual benchmarks from the previous years?

  2. How to assess the benchmarking prediction error for the various methods?

  3. How to determine if the series and its benchmarks are compatible?

Linking

- A monthly survey is being redesign and start publishing new estimates in December 2006.

- The survey is able to produce 2 estimates for December 2006:
  1. The first estimate is based on the old design.
  2. The second estimate is based on the new design.

- There is a 22% difference in level between the two estimates for December 2006.

- The purpose of the linking exercise is to wedge this difference in level back to December 2004, which is the historical anchor point.

- Application of Proc Benchmarking.
Interpolation

- Interpolate monthly values of a stock variable measured in December every year.
- Benchmarking vs Natural Spline (Proc Expand)
- Application: Use spline interpolation to interpolate benchmarking ratios for a stock variable.
Conclusions

- Developments in time series at Statistics Canada from the Time Series Research and Analysis Centre (TSRAC):
  1. Seasonal Adjustment (X-12-ARIMA or Proc X12),
  2. Reconciliation and Raking (Proc TSRAKING),
  3. Benchmarking of flow series (Proc Benchmarking),
  4. Linking (Proc Benchmarking),
  5. Interpolation or Benchmarking of stock series (Proc Expand).

- TSRAC also provides consultation services and training.

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