Comparison of Time Series Characteristics for Seasonal Adjustments from SEATS and X-12-ARIMA

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Two widely-used seasonal adjustment programs are the U.S. Census Bureau's X-12-ARIMA and the SEATS program for ARIMA-model-based signal extraction written by Agustin Maravall. In previous studies with SEATS and X-12-ARIMA, we found some series where the adjustment from SEATS had smaller revisions than the adjustment from X-12-ARIMA (Hood, Ashley, and Findley, 2000). Based on this previous work, I will investigate the properties of a time series that make it a good candidate for adjustment by SEATS or by X-12-ARIMA. I used a version of X-12-ARIMA that has access to the SEATS algorithm. This allows computation of similar diagnostics for both programs — including sliding spans and revision diagnostics — to compare adjustments between the two programs.

In our earlier studies, we found that SEATS needs more diagnostics before we can recommend using SEATS for production work at the Bureau. In this paper, I show examples of why the diagnostics in X-12-SEATS are very useful. For example, SEATS can induce residual seasonality into the seasonally adjusted series when the original series isn't seasonal. The spectral diagnostics available in X-12-SEATS are very important to be able to see if the original series is seasonal or not. I also show an example of a series with very large revisions due to the model chosen by TRAMO. The revision history diagnostics are very useful to see series with large revisions.

1. BACKGROUND

1.1 TRAMO/SEATS, X-12-ARIMA, and X-12-SEATS

TRAMO/SEATS and X-12-ARIMA are based on two different methods for seasonal adjustment. TRAMO (Time series Regression with ARIMA noise, Missing observations, and Outliers) and SEATS (Signal Extraction in ARIMA Time Series) are linked programs developed by Agustin Maravall and Victor Gomez to seasonally adjust time series using ARIMA model-based signal extraction techniques. SEATS uses signal extraction with filters derived from an ARIMA-type time series model that describes the behavior of the series. This method is based on work by Burman (1980) and Hillmer and Tiao (1982), among others. See also Maravall (1993) and Gomez and Maravall (1997a).

X-12-ARIMA is the Census Bureau's latest program in the X-11 line of seasonal adjustment programs. X-12-ARIMA uses signal-to-noise ratios to choose between a fixed set of moving-average filters, often called X-11-type filters. X-12-ARIMA is based on the well-known X-11 program (Shiskin, Young, and Musgrave, 1967) and Statistics Canada's X-11-ARIMA and X-11-ARIMA/88 (Dagum, 1988). Major improvements in X-12-ARIMA over X-11-ARIMA/88 are discussed in Findley, Monsell, Bell, Otto, and Chen (1998). See also U.S. Census Bureau (2002). One of the major improvements is the addition of several types of model and seasonal adjustment diagnostics.

Not only do SEATS and X-12-ARIMA have very different approaches to seasonal decomposition, the programs also have very different seasonal adjustment diagnostics. SEATS diagnostics consist mainly of model-fit diagnostics. X-12-ARIMA diagnostics include spectral plots and stability diagnostics such as the revision diagnostics, both of which are discussed below.

The Census Bureau, with permission and assistance from Agustin Maravall, has a version of X-12-ARIMA with access to SEATS, which in this paper is called X-12-SEATS. X-12-SEATS is not currently distributed by the Census Bureau. X-12-SEATS allows us to compare diagnostics from X-11/X-12-type adjustments and SEATS adjustments with ease using the same spectral diagnostics, revision history diagnostics, and sliding spans diagnostics.

X-12-SEATS also outputs graphics files in a format compatible with X-12-Graph, the companion graphics package for X-12-ARIMA (Hood, 2002). The user can input both X-11/X-12-type adjustments and SEATS adjustments from X-12-SEATS into X-12-Graph and compare diagnostics and adjustments across programs, including graphs from the revision history diagnostic.

1.2 Judging the quality of the adjustments

How do we judge between the two adjustments? This has been a much debated question in the statistical literature; see for example Bell and Hillmer (1984).

Although the model-fit diagnostics in TRAMO and X-12-ARIMA are very similar, they shouldn't be used to judge the quality of the adjustment. SEATS uses filters based on the model. X-12-ARIMA uses the model only to estimate regression coefficients and to forecast the series before adjustment with the X-11-type filters.

For the purpose of judging quality at the Census Bureau, we base our decisions on the presence of residual seasonal or calendar (trading day or holiday) effects. For

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This paper reports the general results of research undertaken by Census Bureau staff. It has undergone a more limited review than official Census Bureau publications. This report is released to inform parties of research and to encourage discussion.

an adjustment to be acceptable, there should be no residual seasonal or calendar effect present in the seasonally adjusted series or in the irregular component. For this paper, I used the spectral graphs, discussed below in Section 1.2.1, to look for the presence of residual seasonal effects.

Because revisions in the seasonally adjusted series are important at the Bureau, I also looked at revisions for the seasonally-adjusted series. By revisions I mean the change or percent change from the initial estimate to the final estimate for any given point. In Section 1.2.2., I discuss the revision diagnostics I used.

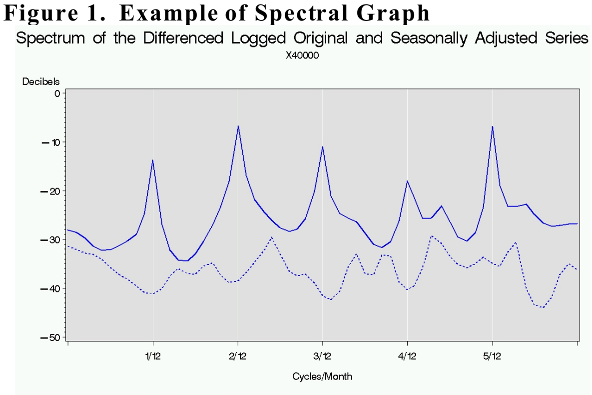
Diagnostics to check for residual seasonality and trading day effects and diagnostics to measure the revisions are readily available in X-12-ARIMA, but they are only easily available for SEATS adjustments through X-12-SEATS.

1.2.1 Spectral Graphs for Residual Seasonality

X-12-ARIMA automatically estimates three spectra whenever seasonal adjustment is requested: the spectrum of the differenced original series, the spectrum of the differenced seasonally adjusted series, and the spectrum of the final irregular component. Seasonal frequencies are marked by vertical lines at k/12 cycles/month for $1 \le k \le 5$. Trading day frequencies are marked by vertical lines at 0.348 and 0.432 cycles/month. (See Cleveland and Devlin, 1980.) A visually significant peak at any of the seasonal or trading day frequencies for either the seasonally adjusted series or the irregular is a signal of a possible residual seasonal or trading day effect.

See Figure 1 for an example of a spectral graph with seasonal peaks in the original series (solid line). Notice the seasonal peaks are suppressed in the spectrum of the seasonally adjusted series (dotted line).

Figure 1. Example of Spectral Graph



1.2.2 Revision History Diagnostics for Revisions to the Seasonally Adjusted Series

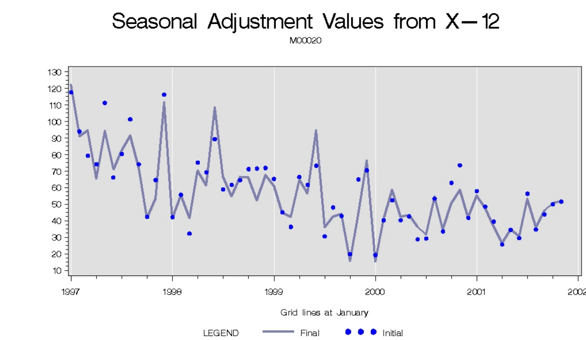
The revision history procedure computes a sequence of runs from truncated sets of data. This allows the user to compare revisions from the initial estimate to the most recent estimate.

Let X_t be a time series defined for t=1,2,...,N. Let $A_{n|T}$ be the seasonal adjustment of X for observation n calculated using $X_1, X_2, \ldots, X_T$, where $n \le T \le N$. Define $A_{n|n}$ to be the *initial* or concurrent seasonal adjustment — the first seasonal adjustment for observation n. Define $A_{n|N}$ to be the *final* or full-series seasonal adjustment — the seasonal adjustment for observation n including all the data up to observation N.

Revisions can be quantified by the mean and maximum absolute percent difference between the initial and final estimate for the seasonal adjustment and between the initial and final estimate of the percent change for the seasonal adjustment. I looked at graphs of the initial and final adjustments.

Figure 2 below shows the final seasonally adjusted series and the initial estimates for every month from January 1997 to November 2001.

Figure 2. Example of Seasonal Adjustment Revision Graph (Final and Initial) from X-12-ARIMA



For this series, there exist several differences between the initial estimates of the seasonally adjusted series and the final estimate of the seasonally adjusted series. You will notice that the points at the end of the series agree more closely, which is to be expected, because at the end of the series, there are not as many new data points between the initial estimate and the final estimate of the seasonally adjusted series.

The history procedure can also generate historical likelihood statistics and historical forecast errors from the regARIMA model estimation. This information helps users make difficult decisions about transformations and regression effects.

Note: When running the revision history diagnostic for SEATS adjustments, I followed the advice of Gomez and Maravall (1997b) to reduce instability. Before I ran X-12-SEATS, I fixed the transformation choice, the model, and the existing outliers. To be consistent, in X-12-ARIMA I also fixed the transformation choice, the model, the existing outliers, and the X-11 options, including the length of the seasonal filter. By default, X-12-ARIMA choose a seasonal filter for the last iteration of the program based on a signal to noise ratio called the Global Moving Seasonality Ratio (GMSR). I set the seasonal filter to be the same for all iterations of the program according to the value of the GMSR. I allowed X-12-ARIMA to reestimate the model parameters as in TRAMO/SEATS.

2. METHODS

For these preliminary results, I started with 260 U.S. Import/Export series from the Census Bureau's Foreign Trade Division.

I used TRAMO to get the ARIMA model for both types of adjustments. I used X-12-SEATS to get seasonal adjustments and revision diagnostics from both an X-11/X-12-type adjustment and a SEATS adjustment, using either an "x11" or a "seats" spec in the input file to X-12-SEATS.

In the example input file for X-12-SEATS shown below, the x11 spec is commented out (with the #), and a seats spec is used for producing the seasonal adjustment.

Example Input File for a SEATS Run

```
series {file = 'm00020.dat'
  format = 'datevalue'
  savelog = peaks}
transform {function = log}
arima {model = (0,1,1)(0,1,1)}
outlier {types=all}
forecast {maxlead = 24}
check {print = all }
slidingspans {savelog=percent}
history { estimates= (fcst aic
  sadj sadjchng) }
#x11 {  }
seats {  }
```

On the subset of series with different adjustments and different revision diagnostics, I examined the characteristics of the series using scatterplots.

The version of X-12-SEATS I used was from April 2002 and contained SEATS 2000 code.

3. PRELIMINARY RESULTS

Out of the 260 Import/Export series, there were only 25 series where the relative mean absolute deviation (RMAD) was greater than 0.05 for the two adjustments. There were only 18 series where there was a difference greater than 0.5 in the absolute average revision in the seasonal adjustment (AARSA) diagnostic.

One thing I did observe was that series with larger revisions in the X-12-ARIMA adjustments than in the SEATS adjustments had generally large values for Θ_{12} (most greater than 0.95) and values for X-12's I/S ratio less than 5. This means that SEATS is using a very long seasonal filter while X-12 is using a relatively short seasonal filter. Series with larger revisions in the SEATS adjustments than in the X-12-ARIMA had generally moderate values Θ_{12} ($0.4 < \Theta_{12} < 0.6$) and values for the I/S ratio greater than 6, so X-12 is using relatively long seasonal filters compared to SEATS. In other words, the adjustment that comes from a longer filter has smaller revisions than the adjustment from the shorter filter.

For some series I tried longer filters in X-12 in an effort to match the filter lengths from SEATS. The revisions were still smaller from the longer SEATS filters.

It is difficult to draw conclusions from this result, however. The smaller revisions could be due to longer filters, and not longer filters causing the smaller revisions.

Also, longer filters didn't always mean smaller revisions. There were many series where the adjustments and the revisions were almost identical even though the filter lengths used by X-11/X-12 were different from the filter lengths used by SEATS.

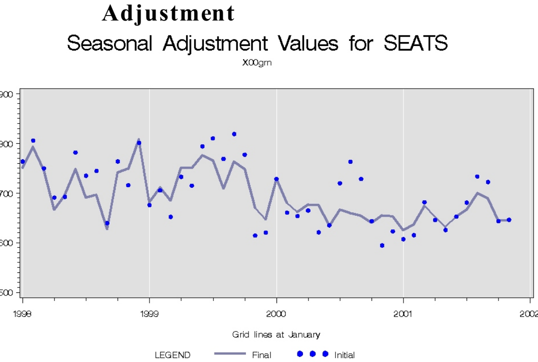
4. EXAMPLES

4.1 Dramatically higher average absolute revisions from SEATS

There were several series where the AARSA for the SEATS adjustment was much larger than for the X-12 adjustment. For all of these series, SEATS would change the model from the one hard-coded into the program — the model chosen by TRAMO. This result holds true in both X-12-SEATS and SEATS (2000 and 2002 versions). Below is an example that demonstrates the problem.

For a grain exports series, X00GRN, TRAMO chose an ARIMA(1 0 0)(1 0 0)$_{12}$ model with a constant, trading day, and Easter regressors. Even though TRAMO's regARIMA model was hard-coded into SEATS, SEATS would sometimes change the model, with very unstable results. SEATS prefers "balanced" models, meaning models where the total AR order, including differencing, equals the total MA order. With a model like the AR model for the X00GRN, SEATS would sometimes use the given model, and sometimes SEATS used several different models, including an airline model. Figure 3 below shows the revisions for the default SEATS adjustment.

Figure 3. Seasonal Adjustment Revision Graph (Final and Initial) from a Default SEATS Adjustment



If I set the model for the SEATS adjustment to the airline model, I can improve the revisions dramatically as shown in Figure 4. With an airline model, instead of the default model from TRAMO, SEATS can find an admissible decomposition with the given model and the revisions are smaller, though still larger than the revisions from the default X-11/X-12-type adjustment, shown in Figure 5 for reference.

Figure 4. Seasonal Adjustment Revision Graph (Final and Initial) from a SEATS Adjustment using the Airline Model (Nondefault)

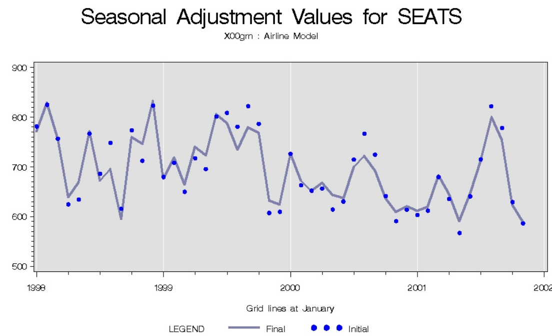
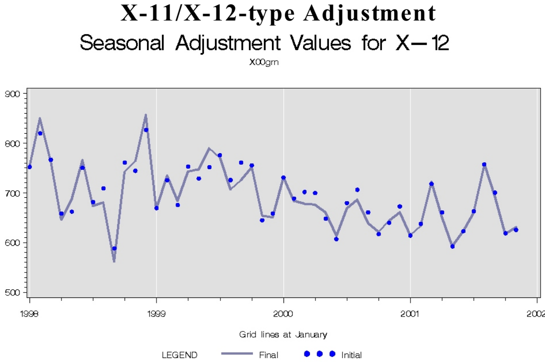


Figure 5. Seasonal Adjustment Revision Graph (Final and Initial) from a Default X-11/X-12-type Adjustment



There is value in looking at the revision diagnostics and setting the model to a balanced model that is less likely to be replaced by SEATS.

4.2 Series That Should Not Be Adjusted

SEATS can induce residual seasonality into the seasonally adjusted series when it's adjusting a series that shouldn't be adjusted. Spectral diagnostics for the original series and the seasonally adjusted series would help to avoid this problem.

In many cases, this occurs when TRAMO chooses a seasonal component in the ARIMA model for a nonseasonal series, and then SEATS changed the model. In most of the examples I have found, TRAMO would choose a seasonal AR(1) model for a series with very little or no seasonality, and SEATS changes the model to a seasonal IMA(1,1), using a seasonal filter for a nonseasonal series.

In Figure 6 note the seasonal peak at 1/12 in the seasonally adjusted series from SEATS where there is no seasonal peak in the original series.

Figure 6. Spectral Graph of the Original and Seasonally Adjusted Series from a SEATS Adjustment

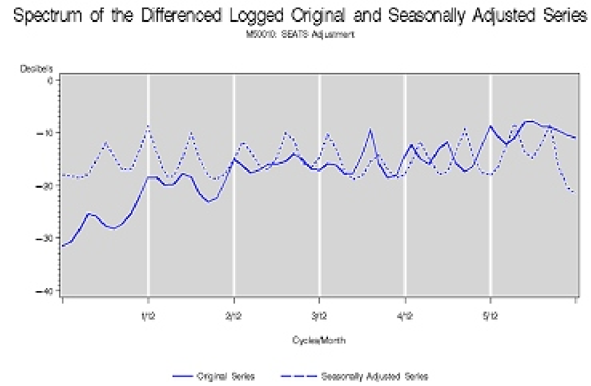
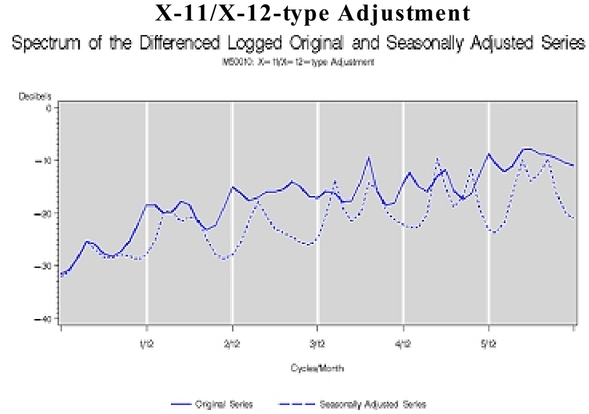


Figure 7 shows a similar spectral graph from an X-11/X-12-type of adjustment for comparison.

Figure 7. Spectral Graph of the Original and Seasonally Adjusted Series from an X-11/X-12-type Adjustment



5. FURTHER STUDY

Because many of the series have such similar seasonal adjustments, I will need a much larger base of series in order to find series where one seasonal adjustment approach has an advantage over the other.

Since the beginning of this study, there are updated versions of SEATS and X-12-SEATS. The analysis needs to be redone with the latest software.

6. CONCLUSION

What are the characteristics of a series that make it a good candidate for a SEATS adjustment?

Though this seems a bit obvious, the series needs to be seasonal. SEATS can induce seasonality into the seasonal adjustment of a nonseasonal series. The spectral diagnostics available in X-12-SEATS are very important to be able to see if the original series is seasonal or not and if there exists residual seasonality in the seasonally adjusted series or the irregular component.

To reduce revisions in the SEATS adjustment, it is also helpful to have a model that SEATS won't change. Therefore, series that are modeled well by the airline model or other balanced models would be better candidates for a SEATS adjustment than series that aren't modeled well by balanced models.

7. ACKNOWLEDGMENTS

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