Supporting Document A
Seasonal Adjustment Diagnostics Checklists

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Census Bureau Guideline
Seasonal Adjustment Diagnostics

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Helping You Make Informed Decisions

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This checklist assumes the reader is familiar with X-12-ARIMA. The *X-12-ARIMA Reference Manual* (U.S. Census Bureau 2004) provides details on X-12-ARIMA. Basic information is contained in the "Getting Started" series (Hood and Feldpausch (2004) and Hood (2004)).

I. First Steps

It is important to look at the data and a graph of the original time series that the reviewer expects to adjust before running X-12-ARIMA for seasonal adjustment. X-12-ARIMA requires three years of data to compute a seasonal adjustment and often more than four years of data to obtain an adequate adjustment. Series with too many zero values in a row will cause estimation problems for X-12-ARIMA and cannot be seasonally adjusted. Large outliers may also cause problems for the adjustment if not properly accounted for. Reviewers should look for changes in pattern and magnitude that suggest they should change the span of data to be used for seasonal adjustment. If a certain span is required for seasonal adjustment, such changes seen in the graph may suggest an appropriate subspan of data for regARIMA (regression and Autoregressive Integrated Moving Average) modeling.

1. Review the data and a graph of the time series.

2. Identify series with fewer than three years of data. This step is particularly important with new series. If a series has fewer than three years, then STOP. The series is not long enough for seasonal adjustment.

For the remaining series (series longer than three years)

3. Identify series with several zero values in a row. Verify that the zero values are valid zeros and not a sign of a problem in creating the data input file. Several zeros in a row could cause estimation problems for X-12-ARIMA, such as nonconvergence of the regARIMA model or poor estimation of the seasonal pattern. See Section VI below for information on possibly combining series.

4. Identify series with possible outlier values (additive outliers, level shifts, and temporary changes). Verify that the outliers are valid and not a sign of a problem in the data by consulting with subject-matter analysts.

5. Identify series with obvious changes, especially in the seasonal pattern. These could be a sign that the series should be shortened. A more consistent pattern in the series will often improve the seasonal adjustment. It is not always easy to identify changes, but subject-matter analysts may know of events (legislative, cultural, etc.) that may affect seasonal patterns. Graphs of the original series and year-over-year graphs are useful for this purpose.

6. If series are part of a composite run, verify that the starting and ending dates for all the series are the same.

7. Run X-12-ARIMA.

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II. Confirming the Presence of Seasonality in the Original Series

For a seasonal series, the spectrum of the original series should have peaks at one or more of the seasonal frequencies, particularly the first four seasonal frequencies (1/12, 2/12, 3/12, or 4/12) for monthly series. Seasonal series also should have a Table F3 M7 diagnostic less than 1.0 and a Table D8 F-test (F-test for seasonality assuming stability) greater than 7.0. If the spectrum, M7 diagnostic, and F-test do not indicate the presence of seasonality, then the series is not seasonal, or its seasonality is not consistent enough for a seasonal adjustment. Such series should not be seasonally adjusted.

If the series is not clearly seasonal, reviewers still should check for other effects, such as trading day and holiday effects, if they are plausible for the series. See Sections IV and VIII of this document.

1. Look at the Spectral Graph of the Original Series. Identify any series without visually significant peaks, as identified by X-12-ARIMA, especially at the first four seasonal frequencies for monthly series.

2. Review the results for the F-test after Table D8 and M7 from Table F3 in the X-12-ARIMA output. Identify any series with an F-test value less than 7.0 and/or an M7 value greater than 1.0. These series should not be seasonally adjusted.

3. Confirm any potential seasonality found in the graph of the original series.

For series with no seasonal and no calendar effects

4. If a series shows no sign of seasonality and no sign of calendar effects, and if the series is published in tables alongside seasonally adjusted series or shown as a component of a composite seasonal adjustment, then in those tables, the original series should be shown as the seasonally adjusted series.

5. If the series is not seasonal and is part of a composite series that is published, verify "`type=trend`" is part of the ***x11*** specification (spec) in the X-12-ARIMA input file so that the series will be included in any totals produced by X-12-ARIMA.

For more information on the spectrum diagnostics and the other X-12-ARIMA measures of seasonality, see the *X-12-ARIMA Reference Manual* (U.S. Census Bureau 2004) and Findley, Monsell, Bell, Otto and Chen (1998).

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III. Additive versus Multiplicative Adjustment

1. Identify series with zero and negative values. These series must be additively adjusted (or combined with other series using a composite adjustment—see Section VI).

For the remaining seasonal series (series with all values greater than zero)

2. Review the results from the automatic transformation choice given by X-12-ARIMA. (Use the ***transform*** spec and set **`function=auto`**, using default settings for other arguments. With this setting, the program automatically chooses the transformation type using Akaike's Information Criterion Corrected for sample size (AICC).)

3. Confirm the results of the automatic choice by looking at graphs of the series.

    a. Look at a graph of the original series. For series with all values greater than zero, identify series in which the size of the seasonal variations increases as the level of the series increases. These series should be multiplicatively adjusted.

    b. If the series has no values less than or equal to zero, look at a graph of the logarithm of the original series. Identify series in which the size of the seasonal variations decreases as the level of the series increases. These series should be additively adjusted.

    For some series, especially those whose level does not change much, the graphs may be inconclusive. In those cases, rely on the automatic choice from X-12-ARIMA.

If the diagnostics for choosing between additive and multiplicative adjustments are inconclusive, or if they indicate only a marginal preference for one type of adjustment, then reviewers should choose to continue using the type of adjustment used in the past to allow for consistency between years.

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IV. Setting RegARIMA Options

If a series is already being seasonally adjusted in production, it is customary to start annual review with the regARIMA model used in production to allow as much consistency between years as possible. If there are deficiencies in the production model, it is helpful to run an automatic modeling procedure to see if the automatically selected model has adequate diagnostics or can be modified to yield a model with adequate diagnostics. Reviewers should compare the results of the production model with the results from an automatic modeling procedure or the model chosen from the identifying sample autocorrelation and partial autocorrelation functions, even if the production model appears to pass all diagnostic tests. Comparing the modeling diagnostics of the two models can reveal deficiencies in the old model (for example, the new model may fit the data better or have lower forecast errors).

If the production model includes seasonal regressors, reviewers are strongly advised to check the need for fixed seasonal effects by removing the seasonal regressors and combining the nonseasonal production model component with a seasonal difference and seasonal moving average (MA) (seasonal (0 1 1)). If the seasonal MA coefficient is significantly different from one (at least two standard errors away from one), then seasonal regressors are not an appropriate model choice.

1. Determine which regression effects, such as trading day or Easter effects, are plausible for the series.

    a. If the effects are not plausible for the series, then reviewers should not fit regressors for the effects. For many series one effect may be plausible but not another.

    b. For series expected to have such effects, review the results from the automatic tests (using AICC) for trading day or for Easter in the ***regression*** spec. Identify the regression model with the minimum AICC for the series. For stock (inventory) series, be sure to test for the correct stock trading day regressor. For stock series, there is no Easter regressor available, so reviewers should not try to fit an Easter effect for a stock series.

    For monthly series, if the automatic test does not indicate the need for a trading day regressor, but there is a peak at the first trading day frequency (0.348) of the spectrum of the regARIMA model residuals, then it may be helpful to fit a trading day regressor manually. If the difference between AICC values for the different models seems small, and the model without a trading day regressor fails the spectrum diagnostic but the model with a trading day regressor passes, then it may be reasonable to model a trading day effect.

    c. If the coefficients for the effects are marginally insignificant, reviewers should determine if there a reason to keep the effects in the model, such as consistency with past years or the effect on other regressors in the model.

2. Note any warning about the normality diagnostics. If the model fails the normality diagnostics, then the t-values for the model coefficients could be affected. (Sometimes a model's failure of the normality diagnostics indicates another outlier regressor should be added to the model. Check the list of outliers that were almost selected (in the output file) and see if any of those outliers should be included as regressors.)

3. Review the current outlier choices.

   a. Identify outlier model coefficients that are not significant, according to the regression t-value. If some outlier coefficients are marginally insignificant, analyze if there a reason to keep the outliers in the model, such as consistency with past years or the effect on other regressors in the model.

   b. Review the list of outliers identified by the automatic outlier procedure. It may be useful to review the list of outliers that were almost selected.

   c. Identify series with a high number of outliers relative to the series' length. Very high numbers of outliers in the regARIMA model can result in regression model overspecification. Reviewers should attempt to remodel the series to reduce the number of outliers. For example, for series that are long enough, reviewers may try to shorten the *full adjustment span* of data and try to remodel the new full span. Reviewers should not shorten the *model span* to reduce the number of outliers if the data values identified as outliers are part of the full adjustment span.

   d. Identify series with outlier regressors in the span of data that might be revised before the next annual review. Consider these regressors carefully because their significance can vary greatly if the underlying data change.

4. Identify high-order ARIMA model coefficients that are not significant. It may be helpful to simplify the model by reducing the order of the model, taking care not to skip lags of autoregressive (AR) models. For moving average (MA) models, it is not necessary to skip model lags whose coefficients are nonsignificant. Before choosing an MA model with a skipped lag, the reviewer should fit the full-order MA model and skip a lag only if that lag's model coefficient is not significantly different from zero.

For series with no seasonal effects

5. If a series is not seasonal, verify that "`type=trend`" is part of the ***x11*** spec in the input file so that the series will be included in any adjustment totals produced by X-12-ARIMA. For a series that shows no sign of seasonality and no sign of calendar effects, be sure that there are no calendar adjustments in the regression model or include "`noapply=(td holiday)`" in the ***regression*** spec. If the series is published in tables alongside seasonally adjusted series or shown as a component of a composite seasonal adjustment, then in those tables, the original series should be shown as the seasonally adjusted series.

For more information on using the spectrum diagnostic for identifying trading day effects, see Soukup and Findley (1999).

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V. Setting *X11* Options

The critical ***x11*** options in X-12-ARIMA are the options that control the extreme value procedure in the X-11 module and the trend filters and seasonal filters used for seasonal adjustment.

1. Verify that the seasonal filters are in agreement generally with the global moving seasonality ratio (GMSR) printed in Table F2.H of the X-12-ARIMA output file. Generally, values of the GMSR less than 2.5 indicate 3x3 seasonal filters are appropriate, and values of the GMSR greater than 6.5 indicate 3x9 seasonal filters are appropriate. The 3x5 filters are generally appropriate when $3.5 \leq \text{GMSR} \leq 5.5$ and are the most common choice for the seasonal filter.

   GMSR values between 2.5 and 3.5 and between 5.5 and 6.5 indicate gray areas where filter choice can vary. Often a 3x5 seasonal filter will be satisfactory for these gray areas. It may be important to maintain last year's seasonal filter choice to avoid large revisions.

   After reviewing the seasonal filter choices, reviewers should set the seasonal filters in the input file to the specific chosen lengths so they will not change during production.

2. Look at the SI-Ratio Graphs from X-12-Graph or Tables C10 and D9 in the X-12-ARIMA output file. Identify any months with many extreme values relative to the length of the time series. Reviewers may need to raise the sigma limits for the extreme value procedure.

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VI. Direct versus Indirect Adjustment

If a time series is a sum (or other composite) of component series, reviewers can sum the seasonally adjusted component series to get a seasonally adjusted aggregate series. This is called the *indirect adjustment* of the aggregate series. An indirect adjustment is usually appropriate when the component series have very different seasonal patterns and many of the series can be seasonally adjusted individually.

Reviewers can also calculate a *direct adjustment* of the aggregate series by summing the components first and then seasonally adjusting the total. A direct adjustment is usually appropriate when the series have very similar observed seasonal components because then adding the series together first will reinforce the seasonal pattern while allowing cancellation of some noise in the series. It is important that the individual series can be grouped together logically. For example, it may be logical to group Exports of Copper and Exports of Tin if they have similar estimated seasonal patterns. It is probably not logical to group Exports of Copper with Exports of Wheat. Direct adjustment of aggregate series may be useful when the individual components cannot be adjusted reliably, perhaps because the components have many zero values.

When adjusting individual component series using factors from the direct adjustment of the total, reviewers should evaluate the resulting adjustments to make sure that there are no residual seasonal or trading day effects. Reviewers can run X-12-ARIMA with the adjusted series as input (but should not perform a seasonal adjustment) and check the Spectral Graph of the Original Series for visually significant peaks, as identified by X-12-ARIMA in the output file. If there are visually significant peaks, then the reviewer should not use that adjustment, and should change the specifications of the direct adjustment or find another logical combination for adjustment.

1. Run the total series as both a direct and an indirect adjustment for the total. Look to see if

   a. the spectrum of the seasonally adjusted series is free of peaks at seasonal frequencies (for monthly series, check frequencies 1/12, 2/12, 3/12, and 4/12)

   b. the sliding spans diagnostics are at or below the accepted cutoffs (see Section X).

   If only one adjustment type passes the spectrum and sliding spans diagnostics, then it is the preferred adjustment. If each adjustment type passes one diagnostic but not another, check to see if the adjustments can be improved so that both pass their diagnostic tests. If each adjustment type passes the diagnostics, then either adjustment is acceptable.

2. Identify the best possible common start date for all the series that are part of an indirect adjustment. To produce an indirect adjustment, the adjustments of all the individual series must begin and end on the same dates. To use a common start date, reviewers may need to shorten some of the series.

   Sometimes the start date is beyond the control of the reviewer, or if one or two series are more important than the others, then the start date might depend on those series. Reviewers with the opportunity to choose a start date should look for breaks in the series, periods with more outliers, and changes in patterns. If there are enough data beyond the break, then the adjustments should start after that date.

3. Verify that all component series, even nonseasonal series, are included in the X-12-ARIMA metafiles. This ensures the series will be included in the composite, and X-12-ARIMA will produce the correct diagnostics for the indirect adjustment.

For individual series that are not seasonal but are part of a seasonally adjusted composite series

4. Verify that the series have an X-12-ARIMA input file that contains "`type=trend`" in the ***x11*** spec so that the series will be included in any totals produced by X-12-ARIMA. If the regression model includes calendar effects, the calendar-adjusted series will be included in the total.

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VII. Identifying Residual Seasonality in the Seasonally Adjusted Series and in the Irregular Component

There should be no residual seasonal effects in published seasonally adjusted series or in the irregular component. Residual seasonality in the seasonally adjusted series or the irregular component can often be eliminated by shortening the span of the data used for modeling or for the adjustment, changing the seasonal filter lengths, or both.

1. Look at the Spectral Graph of the Seasonally Adjusted Series and the Spectral Graph of the Modified Irregular Component. Identify any series with visually significant peaks, as identified by X-12-ARIMA (warnings appear in the screen messages, in the output, and in the log if requested), especially at the first four frequencies for monthly series. (Peaks at 5/12 and 6/12 may be discounted.)

   If there is residual seasonality, as indicated by the spectral peaks above, check the regARIMA model options, the ***x11*** options, and the span of data used for modeling and seasonal adjustment, as necessary, to remove residual peaks.

2. If the series is a composite indirect adjustment of several component series, perform the checks mentioned in 1 on the results for adjustment of the composite series. If there is indication of residual seasonality, then in addition to the corrective measures mentioned in 1, also check to ascertain if any series that are not being seasonally adjusted have seasonal effects. These series may need to be seasonally adjusted for the purpose of the composite series even if the individual seasonal adjustments are not published.

3. If the series is a composite indirect adjustment of several component series, verify that all component series, even nonseasonal series, are included in the X-12-ARIMA metafiles. This ensures the series will be included in the composite and X-12-ARIMA will produce the correct diagnostics for the indirect adjustment.

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VIII. Identifying Residual Calendar Effects in the Seasonally Adjusted Series and in the Irregular Component

There should be no residual calendar effects in published seasonally adjusted series or in the irregular component. Residual calendar effects in the seasonally adjusted series or the irregular component can often be eliminated by adding the appropriate calendar effect to the regression, shortening the span of the data used for modeling, or both.

1. Look at the Spectral Graph of the Seasonally Adjusted Series and the Spectral Graph of the Modified Irregular. Identify any visually significant trading day peaks, as identified by X-12-ARIMA (warnings appear in the screen messages, in the output, and in the log if requested). (For monthly series, if there is a peak only at the second trading day frequency (0.432) and the model has a trading day regressor, then the trading day peak can be discounted.)

2. If the series is a composite indirect adjustment of several component series, look at the Spectral Graph of the Indirect Seasonally Adjusted Series and the Spectral Graph of the Indirect Modified Irregular. Identify any visually significant trading day peaks as identified by X-12-ARIMA.

   If there is a residual trading day effect, as indicated by the spectral peaks above, check for residual trading day effects in the component series. If appropriate, add a trading day regressor as needed to the individual series.

3. Identify any unusual patterns in the outliers or extreme values.

   a. Identify any March–April patterns. Outliers or extreme values that occur frequently in March and April could indicate series with an Easter effect that is not being modeled or is being modeled incorrectly. If an Easter effect is plausible for the series, re-evaluate the Easter regression.

   b. Identify any leap-year February patterns. These patterns could indicate series with the wrong trading day effect. Correct the regression as appropriate. For example, if the model includes a flow trading day regressor for a stock (inventory) series, remove the flow trading day regressor and evaluate the appropriate stock trading day regressor.

   c. Identify any patterns in the outliers or extreme values that occur in the month or months surrounding other moving holidays, such as Labor Day. If such patterns are found that reflect plausible holiday effects, evaluate the appropriate regressors.

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IX. Evaluating the RegARIMA Model

The main modeling diagnostics available in X-12-ARIMA are the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) Graphs and the spectral graphs of the model residuals. It is also helpful to review the model coefficient t-values and the outliers selected.

If there are model deficiencies, see Section IV on setting options for the regARIMA models.

1. Identify any significant peaks in the ACF and PACF graphs of the model residuals. For a monthly series, graphing 36 lags, we would expect to have only one or two correlations above the confidence bounds. If the significant peaks are at the lower lags or the seasonal lags, then try adding MA or AR terms to the ARIMA model to eliminate significant ACF/PACF values. Keep in mind that the order of the seasonal component of the ARIMA model should not be more than one, and the seasonal component of the ARIMA model should not contain both AR and MA parameters.

   Note: We often use the Ljung-Box Q diagnostics (LBQ) as a proxy for the values in the ACF graph. Keep in mind that one big ACF value could result in a model's failure of the LBQ diagnostic for that lag and following lags also. It is always useful to check the ACF graphs in addition to the LBQ diagnostics.

2. Identify any residual seasonality or trading day effects in the spectrum of the model residuals. Try to improve the model to eliminate the residual effects.

3. Note any warning about the normality diagnostics. If the model fails the normality diagnostics, then the t-values for the model coefficients could be affected, though lack of normality in itself is not a sign of model deficiency. Sometimes a model's failure of the normality diagnostics indicates that another outlier regressor should be added to the model. Check the list of outliers that were almost selected (in the output file) and see if any of those outliers should be included as regressors.

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X. Evaluating the Stability of the Seasonal Adjustment

The stability diagnostics for seasonal adjustment are the sliding spans and revision histories. These diagnostics are invoked with the ***slidingspans*** and ***history*** specs in X-12-ARIMA. For most series, about ten years of data are needed to produce four sliding spans and useful history diagnostics. (Reviewers with shorter series should monitor other diagnostics until the series are long enough for sliding spans and history diagnostics.)

Large revisions and instability indicated by the history and sliding spans diagnostics suggest that the seasonal adjustment may not be useful and that X-12-ARIMA may not accurately estimate any seasonal pattern that could be present in the series. If a series fails the stability diagnostics, then reviewers should seriously consider not publishing the seasonally adjusted series. The series still may need to be seasonally adjusted, however, if it is part of a composite series.

It is not necessary to run the stability diagnostics during production; the ***slidingspans*** and ***history*** specs will slow down the X-12-ARIMA runs.

It is important not to sacrifice other diagnostics to improve the revisions. For example, it is possible to improve the stability diagnostics by using very long trend filters and seasonal filters, but the length of the filters used should depend on the noise-to-signal ratios such as the GMSR and not on achieving the smallest revisions possible. It also may be possible to change the regARIMA model to improve the stability, but this should be done only if the new regARIMA model has acceptable modeling diagnostics.

It is also important to remember that changing the filter lengths and the span of data used for modeling and seasonal adjustment can affect the number of observations available for both the sliding spans analysis and the history analysis. Be very careful to compare sliding spans diagnostics only when the number of spans is the same and to compare history diagnostics over the same time span.

1. If the program area expectation for instability of the seasonally adjusted series is relatively high, set the cut-off value to 5% (with "`cutseas=5`" in the ***slidingspans*** spec).

2. Identify series where the sliding spans diagnostic was calculated over four spans and the percentages were too large:

    a. The percentage of months (quarters) flagged as unstable in the seasonal adjustment is larger than 25%, and/or

    b. The percentage of months (quarters) flagged as unstable in the month-to-month (quarter-to-quarter) changes of the seasonal adjustment is larger than 40%.

3. Identify series with large revisions-history diagnostic values compared to the typical revisions for the underlying original time series. It is useful to review the revisions in particular months, especially when using different seasonal filters for different months.

For more information on the sliding spans diagnostics, see Findley, Monsell, Shulman, and Pugh (1990). For more information on the history diagnostics, see the *X-12-ARIMA Reference Manual* (U.S. Census Bureau 2004) and Findley, Monsell, Bell, Otto and Chen (1998).

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XI. Managing the Process:

1. Ask someone who knows X-12-ARIMA syntax to proofread your X-12-ARIMA input files.

2. Identify any series containing major changes to the input specification file for X-12-ARIMA (to filters, regressors, type of adjustment). Discuss the consequences of the changes with the subject-matter analysts.

3. Refer to the *X-12-ARIMA Reference Manual* (U.S. Census Bureau 2004) for information on options and syntax.

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