Seasonal Adjustment of the Quarterly Tax Survey (QTax)

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Abstract
The U.S. Census Bureau conducts the Quarterly Summary of State and Local Government Tax Revenue Survey. The survey collects local property taxes, state taxes, and local nonproperty taxes. Many of these time series display a seasonal pattern, and so in this paper we investigate options for seasonally adjusting four different time series at national and state levels, using the seasonal adjustment software X-13ARIMA-SEATS. For each studied characteristic, we compare the adjusted series obtained via the semiparametric X-11 method to the corresponding adjusted series obtained via the model-based SEATS method on a set of predetermined diagnostic measures. We also consider direct and indirect adjustment of each national series. The seasonally adjusted series would provide additional information for data users, and would be a supplement to – not a replacement for – the current data products.

Key Words: Trading Day, X-11, SEATS, Diagnostic, Stability, Residual Seasonality, Time Series

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

1. Background

The U. S. Census Bureau's Quarterly Summary of State and Local Government Tax Revenue Survey (QTax) measures United States state governments' and local governments' tax revenue. The QTax survey is a combination of three surveys/forms: F-71 for local property taxes, F-72 for state taxes, and F-73 for local nonproperty taxes. The quarterly state tax statistics are obtained from a census of all state governments and do not include local governments' tax revenues. Local governments' tax revenues are obtained from probability samples, specifically a stratified cluster sample of local property tax collectors for property tax and a stratified sample of local tax imposers for nonproperty taxes. The Census Bureau publishes the national series and state series. The local series (an estimate of the national total of combined local governments' tax revenues) is derivable by subtraction of the total of the combined state series from the national total. Information about the data collection and estimation methodology as well as the time series data are available at https://www.census.gov/govs/qtax/.

Many of the QTax time series are cyclical, following a regular, repetitive annual pattern of scheduled tax collection. Year-to-year comparisons typically include values from the same calendar quarter, to avoid comparisons of different points during the cycle. In other words,

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these seasonal patterns have been noted, and evaluations take this seasonality into account. A natural question to ask is whether seasonal adjustment could reveal more about the underlying quarter-to-quarter movement than has been apparent from the original series. If so, then the seasonally adjusted series would provide additional information that could help the data users gain insight into the underlying trend changes and would serve as useful supplements to – not replacements for – the current data products.

Our investigation studies four QTax items: Property Tax (T01), Sales Tax (T09), Income Tax (T40), and Corporate Income Tax (T41). We consider the national, state, and local series for each item, for a total of 12 time series. (We consider only the combined estimates at the national level, that is, we do not consider adjusting each individual state government's time series). As a general principle, the Census Bureau adjusts only series that appear to have a verified seasonal pattern and publishes adjusted series that no longer exhibit seasonality in the seasonal or irregular components. Consequently, even if a series has a verifiable seasonal pattern, publication of a seasonally adjusted series is not guaranteed. To obtain quality seasonal adjustments for the considered series, we compare alternative adjustments on the same series obtained via X-11 and via SEATS (Signal Extraction in ARIMA Time Series), direct versus indirect adjustment of national series, and other modeling considerations such as identification and treatment of outliers and potential trading day effects.

Section 2 gives an overview of seasonal adjustment with X-13ARIMA-SEATS, providing detail on the available methods and diagnostics. Section 3 walks through the complete investigation, describing the preliminary analyses and associated decisions before providing model fitting and validation specifics for each series. We conclude in Section 4 with recommendations for the QTax series in the foreseeable future and a few general comments.

2. Seasonal Adjustment with X-13ARIMA-SEATS

The Census Bureau develops and maintains X-13ARIMA-SEATS software for seasonal adjustment of time series (Time Series Research Staff 2017). The current release follows the earlier X-11 (Shiskin, Young, and Musgrave 1967), X-11-ARIMA and its subsequent releases (Dagum 1988), and X-12-ARIMA (Findley, Monsell, Bell, Otto, and Chen 1998). X-13ARIMA-SEATS has the functionality of the previous software, including the traditional X-11 moving average method of seasonal adjustment, and additionally allows for the SEATS autoregressive integrated moving average (ARIMA) model-based seasonal adjustment method (Gómez and Maravall 1996).

Seasonal adjustment involves the decomposition of a series into a trend-cycle component (C), a seasonal component (S), and an irregular component (I). The trend-cycle is the local level of the series, and includes cycles that are longer than a year. The seasonal component consists of effects occurring in the same quarter each year that are in the same direction and with roughly the same magnitude. Irregular effects are what is left over; these effects are unpredictable in timing, duration, and impact. For a time series Y, a multiplicative decomposition is $Y = S \times C \times I$ and the seasonally adjusted series is $A = C \times I = Y/S$.

The models we fit in X-13ARIMA-SEATS are regression models with errors that follow an ARIMA process, known as regARIMA models. RegARIMA models in X-13ARIMA-SEATS, with the ARIMA model (p d q)(P D Q), follow the form

$$\phi(B)\,\Phi(B^s)(1-B)^d(1-B^s)^D\,(y_t - \textstyle\sum_i \beta_i x_{it}) = \theta(B)\,\Theta(B^s)\,a_t \qquad (1)$$

where
t is a time index,
y_t is the original (or transformed original) time series,
β_i are regression parameters,
x_{it} are regression variables,
B is the backshift operator such that $B^k z_t = z_{t-k}$,
s is the seasonal period (four for quarterly series such as QTax),
$\phi(B) = (1 - \phi_1 B - \ldots - \phi_p B^p)$ is the nonseasonal autoregressive (AR) operator of order p,
$\Phi(B^s) = (1 - \Phi_1 B^s - \ldots - \Phi_P B^{Ps})$ is the seasonal AR operator of order P,
$\theta(B) = (1 - \theta_1 B - \ldots - \theta_q B^q)$ is the nonseasonal moving average (MA) operator of order q,
$\Theta(B^s) = (1 - \Theta_1 B^s - \ldots - \Theta_Q B^{Qs})$ is the seasonal MA operator of order Q,
d is the nonseasonal order of differencing,
D is the seasonal order of differencing, and
a_t is a series with values that are independent and identically distributed with mean zero and finite variance.

Note that X-13ARIMA-SEATS estimation of AR and MA parameters enforces certain constraints to satisfy stationarity and invertibility assumptions needed for adequate forecasts. For discussion of these concerns and more information on the models available in the software, see the X-13ARIMA-SEATS Reference Manual (Time Series Research Staff 2017).

Regardless of whether X-11 or SEATS is used for seasonal adjustment, the fitted regARIMA models may estimate trading day effects (activity related to the day of the week), moving holiday effects (activity related to holidays whose effects are not consistently confined to a particular quarter), and outlier effects; the significant effects are included in the $\sum_i \beta_i x_{it}$ term.

Trading day effects are subtle in quarterly time series. McDonald-Johnson, Findley, and Cepietz (2009) found that for quarterly series derived from monthly series with known trading day effects, the trading day regressors most often were not identified using the tests that are in X-13ARIMA-SEATS, but for the series whose trend components were smoother and irregular components were less variable, significant trading day effects could be identified. The QTax series seem to be consistent enough to fall into this category where we could identify trading day effects if they are present. Because they measure government activity, the QTax series might be expected to show higher levels on weekdays and lower levels of weekend activity, which could be detected via testing of trading day effects. X-13ARIMA-SEATS has likelihood tests and significance tests available for determining whether the regressors are adequate. We used a combination of Akaike's Information Criterion corrected for sample size and t tests (for one-coefficient trading day regression) or F tests (for six-coefficient trading day regression) to evaluate whether trading day effects were present in the series.

Multiple outlier effects are available as regressors in X-13ARIMA-SEATS. The three most common outlier types are additive outliers, or point outliers, abbreviated as AO*yyyy.q* (for example, AO2016.1 for a point outlier at the first quarter of 2016); level shifts, or abrupt changes of the series level, abbreviated as LS*yyyy.q*; and temporary changes, or abrupt changes to the series level followed by a steady return to the previous level, abbreviated as

TC*yyyy.q*. X-13ARIMA-SEATS can identify these three types automatically, or they can be hard-coded as regression variables so that the program estimates them as part of the model every time (Time Series Research Staff 2017, Section 4.3).

Once the regARIMA model is determined, it has different functions in the X-11 and SEATS methods of seasonal adjustment. In X-11, the regARIMA model is for forecasting and for treatment of outlier, trading day and moving holiday effects. With the SEATS method, the ARIMA model determines the seasonal adjustment filter.

X-13ARIMA-SEATS includes a number of diagnostics for checking the adequacy of the model, the stability of the seasonal adjustment, and the presence of seasonality in the series and residual seasonality in the adjusted series. For quarterly series, the QS diagnostic, which looks for positive autocorrelation at seasonal lags, is an effective diagnostic in determining whether a series is seasonal (Lytras 2015).

Series that are composites of other series, as is the case with the QTax series, present options for seasonal adjustment. One method is direct seasonal adjustment, where all modeling and adjustment choices apply directly to the series itself. Another method is indirect seasonal adjustment, where the adjustment is derived from the adjustments of the components. For instance, we could seasonally adjust National T01 indirectly by summing the direct seasonal adjustments of State T01 and Local T01. Conversely, we could seasonally adjust Local T01 indirectly by subtracting the direct seasonal adjustment of State T01 from the direct seasonal adjustment of National T01. X-13ARIMA-SEATS provides diagnostics for composite seasonal adjustments when that method is used.

3. Adjusting the QTax Series

3.1 Preliminary Analysis

Initially we had the series values from first quarter 1992 through second quarter 2015, and we planned to use the entire set of available estimates. We started from scratch, and we wanted to allow for either X-11 or SEATS seasonal adjustments. Immediately, we noticed tangible differences between corresponding X-11 and SEATS adjustments. Figure 1 presents a graph of the State T40 series. Quarter 2 (Q2) is consistently a peak, but the height of the peak changes frequently. Figure 2 shows the X-11 seasonally adjusted series in blue, with the overlaid SEATS seasonally adjusted series in purple. In years where the Q2 peak is high in the original series, the X-11 adjustment retains the Q2 peaks. In contrast, the SEATS adjustment smooths these peaks in all years.

We question which adjustment is better: are the taller than usual Q2 peaks evidence of changing seasonal patterns, indicating that the SEATS adjustment is better because it removes them; or is the activity level in these years higher compared to others and so the X-11 adjustment is better because it maintains that information? Regardless, the use of SEATS adjustments in addition to or in place of X-11 adjustments seemed to warrant further investigation.

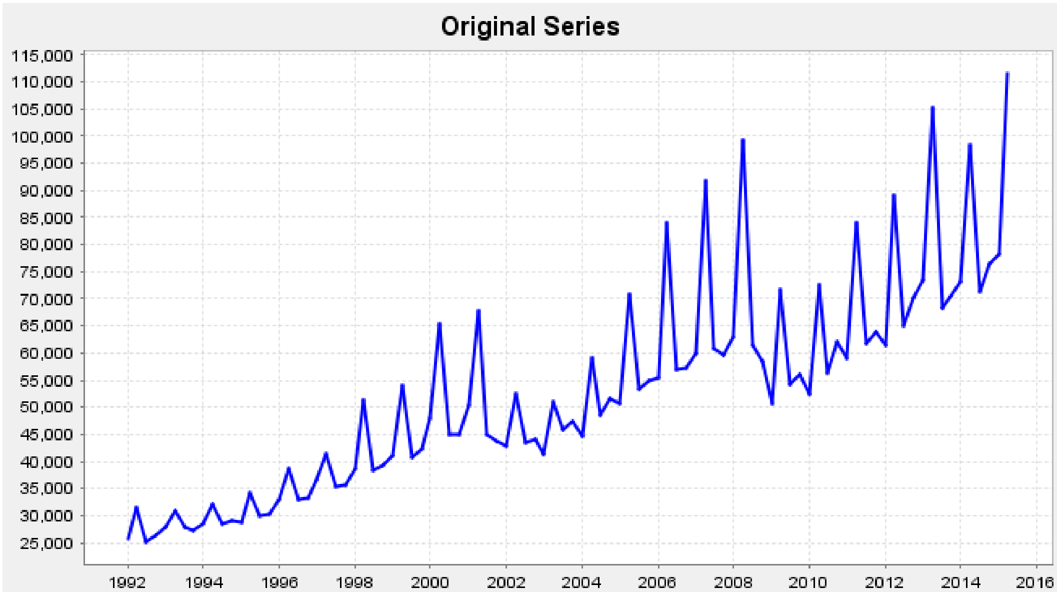

Figure 1: State T40 Series

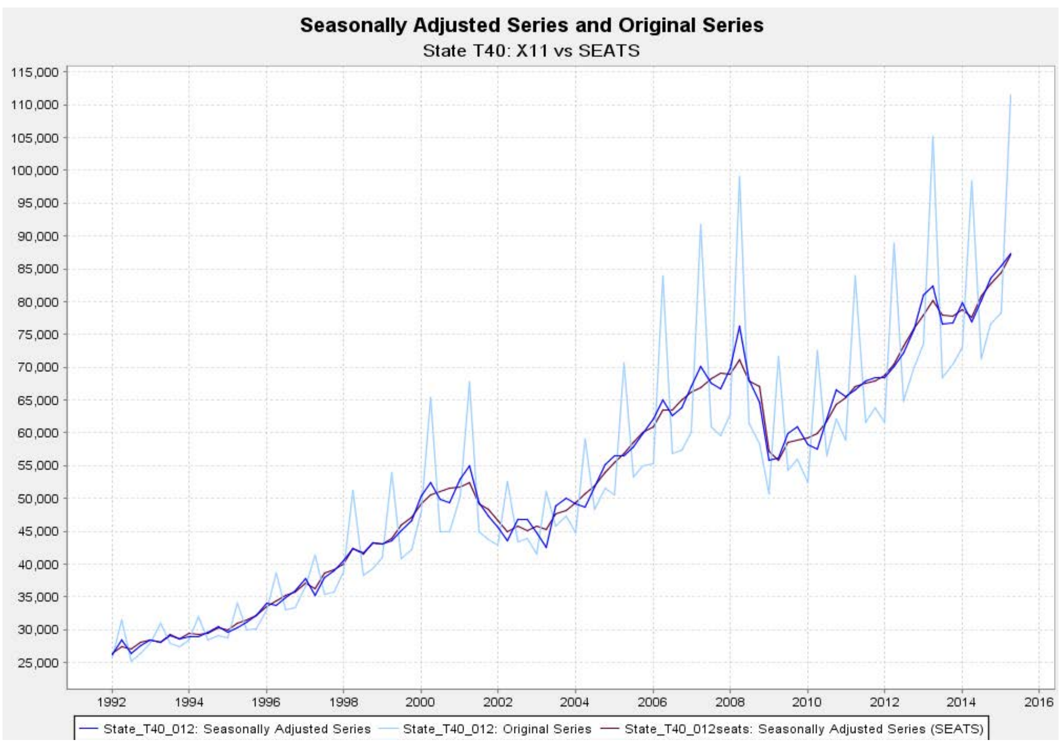

Figure 2: X-11 and SEATS adjusted State T40 Series

As we worked with the full set of estimates, we found an apparent change in the seasonal pattern occurring in the late 2000s in some of the series. Figure 3 presents the full State T01 series, which seems to have a sudden change in the seasonal pattern in 2005. The change is more evident in the year over year graphs of the series shown in Figure 4. Specifically, the series has a consistent pattern with troughs in quarters 1 and 3 and peaks in quarters 1 and 2 from 2005 forward, whereas the pattern was less consistent prior to 2005.

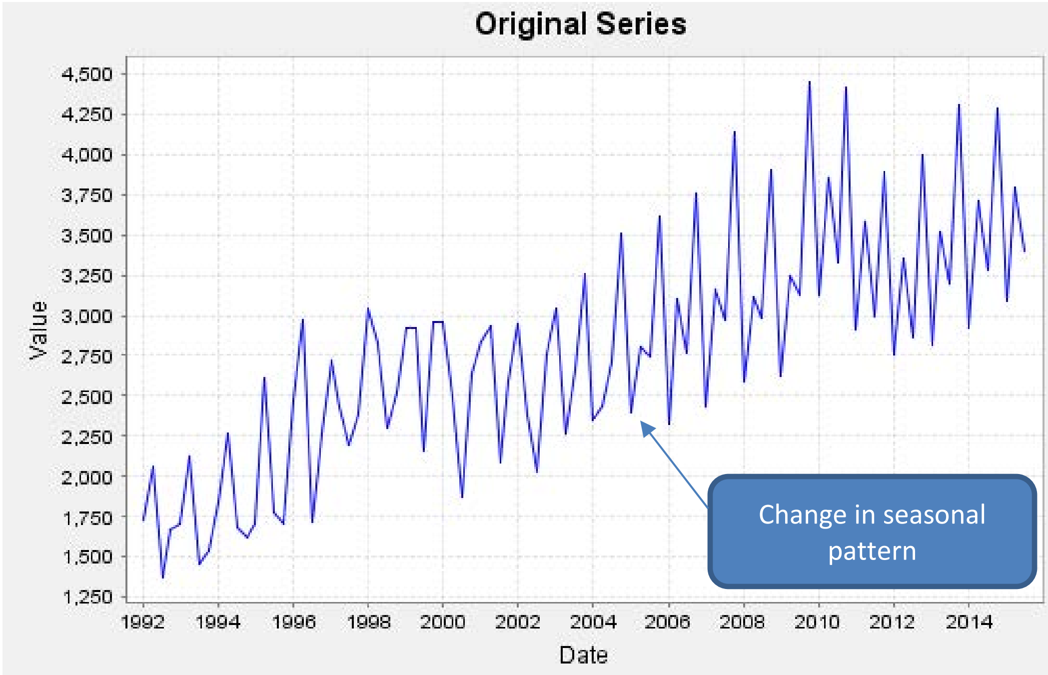

Figure 3. State T01, which exhibits a changing seasonal pattern in 2005

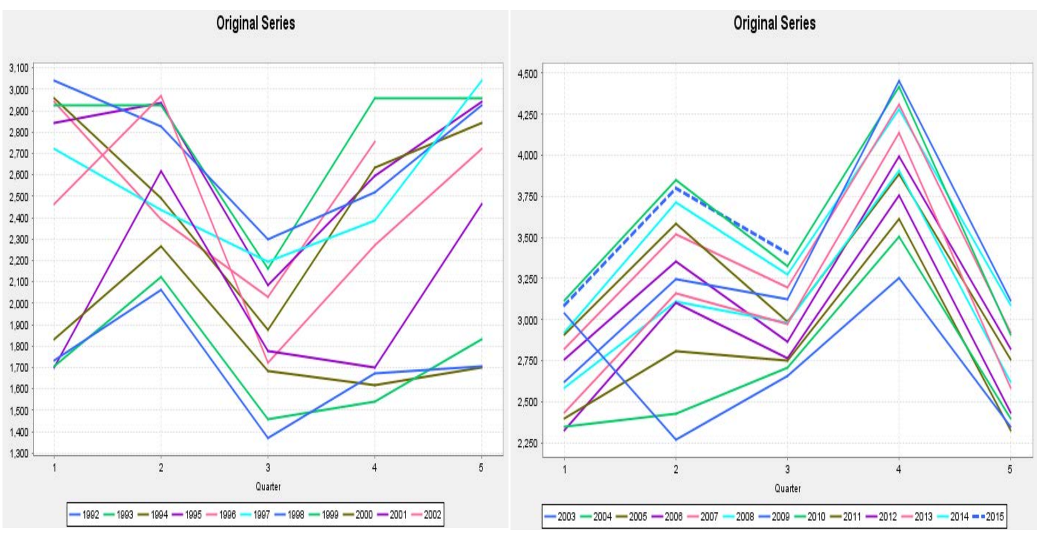

Figure 4: State T01 by year. The first plot shows a line for each year from 1992-2002, and the second for 2003-2015

Although the change in the seasonal pattern was evident in this series, none of the subject matter experts could identify any single cause.

In contrast, we have an explanation for the change in the seasonal pattern for the Local T01 series shown in Figure 5 below. Beginning in 2007, the QTax survey began replacing the existing nonprobability sample design collecting local government measurements with probability samples, as discussed in Section 1. By 2009, the new probability samples were fully phased in. The seasonal pattern in the National T01 series, although retaining the same quarterly highs and lows, increased in variance and the behavior of the third quarter, in particular, became less regular. The vertical red line shows us when the probability sample was fully utilized.

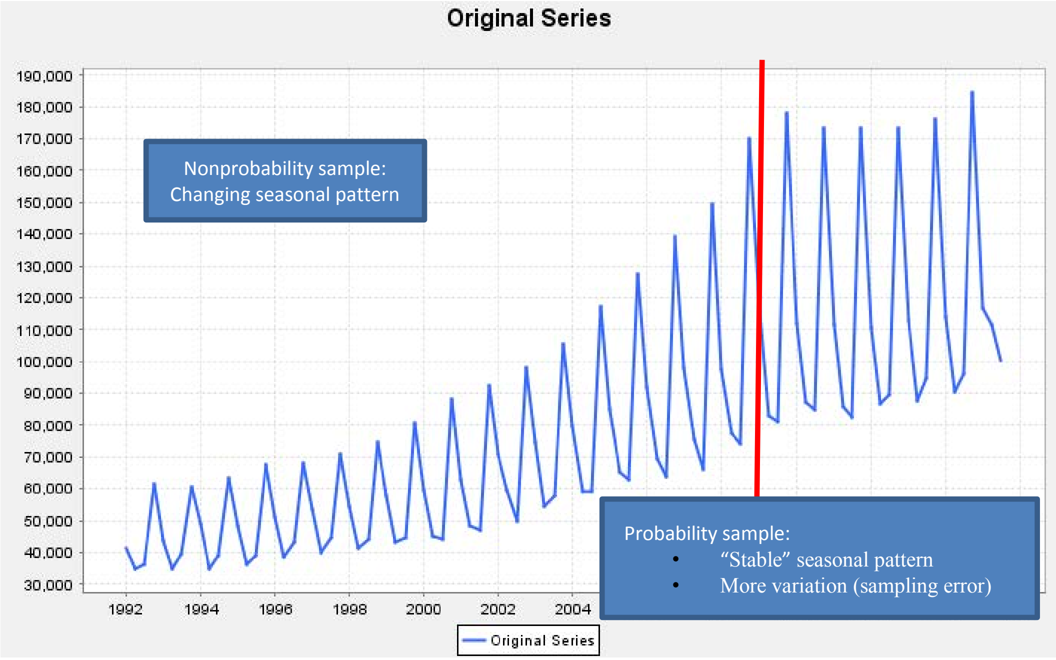

Figure 5: National T01 series

The local component estimates of tax items T09, T40, and T41 are from the same survey (F-73). Starting in the third quarter of 2013, the scope of the data collection was reduced from eleven taxes to three. We investigated whether a change in seasonal pattern occurred at that time for these series but found no significant effect.

In consultation with the subject matter experts, we ultimately chose to start all series in 2009 instead of 1992. This was the logical decision for the local series, as the target populations changed with the sample design. Of course, we could have used the full set of tabulations for the state series. Longer series allow more options for adjustment, but the corresponding (item code) series show a lack of comparability. The shorter series provide less data than we would like for analysis and limit the standard diagnostics that would be available with a larger collection of data points. Despite these concerns, we chose to use the shorter series, eliminating several series changes that had no obvious cause and allowing for the possibility of employing either direct or indirect estimation of the national series[2].

3.2 Model and Adjustment Options

Once we decided to adjust the series starting in 2009, we had to refit the series models. At this point, we had seven years of data through fourth quarter 2015. Table 1 shows the regARIMA model and the X-11 seasonal filter selected for each series.

[2] Direct adjustments seasonally adjust the aggregated component series (i.e. the national series). Indirect adjustments seasonally adjust each component series and aggregate those adjustments (i.e. aggregate the local and state series, then add the adjusted series to obtain the seasonally adjusted national series).

With the full span, trading day effects were found in four of the series. For both State and National T09, the automatic trading day test of X-13ARIMA-SEATS selected the full 6-coefficient trading day, which models each day of the week individually. For State and National T41, 1-coefficient trading day was significant. The 1-coefficient trading day effect constrains Monday through Friday to one effect and Saturday and Sunday to an offsetting effect (the sum of the effect is constrained to zero). Perplexingly, for both State and National T41, the estimated trading day effect was negative for weekdays and positive for Saturday and Sunday, the opposite of what we would expect for government activity, so we suspected that the significance was a spurious result and not indicative of a real trading day effect. With the shorter span, only one series had evidence of trading day effects. State T01 did not have a significant trading day effect with the full span, but with the shorter span, the automatic test of X-13ARIMA-SEATS selected the 1-coefficient trading day effect, which was positive for weekdays.

Table 1 shows the models, regression effects, and X-11 filters selected for each series. For the three T41 series (Corporate Income Tax), the ARIMA models selected had a seasonal (1 1 0) component, which is rather atypical; a seasonal (0 1 1) component is used much more often for series at the Census Bureau. We had only minor concerns with the diagnostics when the series were run through Q4 2015 with the selected models, so we tentatively went forward with those models.

The adjustments showed no evidence of residual seasonality with one exception, discussed in the next paragraph. However, not all of the series had a stable seasonal adjustment. The sliding spans diagnostic (Findley, Monsell, Shulman, and Pugh 1990) indicated that the adjustments of Local T09, Local T40, and Local T41 were unstable. (This measure of instability is according to the sliding spans criteria designed for use with four spans to compare; because of the short length of the series, only three spans were available. Typically, with three or fewer spans, the diagnostic flags fewer unstable periods, so the adjustments certainly were unstable.) Despite the instability in these three local series, the indirect adjustments of all the national series were stable according to their sliding spans diagnostics. This may be due to the state series' dominance of T09, T40, and T41.

Local T09 is questionably seasonal with the full span and has conflicting diagnostics using the short span. For the original series, the QS had an associated p-value of 0.86, indicating a lack of significant seasonality, although the QS of the outlier-adjusted series had a p-value of 0.04, indicating some evidence of seasonality. When we modeled seasonal regressors for the series, the F test had a p-value of 0.00, again indicating significant seasonal effects. Because of the questionable seasonality in the series, we compared two indirect adjustments of National T09: (1) seasonally adjusting both State T09 and Local T09 and (2) adjusting State T09 but adding the original unadjusted Local T09 into the indirect adjustment. The indirect adjustment of National T09 when Local T09 was not seasonally adjusted had evidence of residual seasonality. Both the QS of the seasonally adjusted series adjusted for extreme values and the QS of the irregular adjusted for extreme values had p-values less than 0.01. The QS of the series without the extreme adjustment did not indicate residual seasonality. Based on these diagnostics, we were uncomfortable with recommending either of the considered indirect adjustment procedures.

Series		RegARIMA Model	X-11 Filters
Local	T01	(0 0 0)(0 1 0) + constant	3x5 3x5 3x3 3x5
State		(0 1 1)(0 1 1) + TD(1coef) + LS2009.3 + TC2015.1	3x5 3x5 3x3 3x5
National		(0 0 0)(0 1 0) + constant	3x5 3x5 3x3 3x5
Local	T09	(0 1 1)(1 0 0) + AO2010.4	3x3
State		(0 1 1)(0 1 1)	3x3
National		(0 1 1)(0 1 1) + AO2010.4	3x3 3x3 3x5 3x5
Local	T40	(0 1 1)(0 1 1) + LS2011.1	3x3
State		(1 0 0)(0 1 1) + constant	3x3
National		(0 1 0)(0 1 1)	3x3
Local	T41	(1 0 0)(1 1 0) + constant + TC2010.1	3x5
State		(0 0 0)(1 1 0) + constant + TC2009.2	3x5
National		(1 0 0)(1 1 0) + constant	3x5

Table 1. Models and X-11 filters from the review of the series with span starting in 2009

3.3 Monitoring the Adjustments

Although the adjustments appeared to be of sound quality, the series were relatively short and the Census Bureau had never published them on a seasonally adjusted basis before, so we followed the precedent of the introduction of the Quarterly Services Survey seasonal adjustment, tracking the results for a while to ensure that the results would remain consistent (Hutchinson and Wong 2009). Consequently, after selecting the model and adjustment options for the series, we entered a monitoring phase. The monitoring phase also would allow us to re-evaluate the choices of models and adjustments of each series. Each quarter in 2016, as new series values were available, we ran the adjustments as well as a SAS®[3] program, which:

- gathered diagnostics to check whether the selected model continued to work well
- examined the changes in the model parameters and regression coefficient estimates
- looked at whether new outliers were selected
- checked whether the previous month's forecasted value was close to the true value
- read the seasonally adjusted series and compared it with that of previous quarters to see how much previous estimates were changing when new values were added
- compared the direct and indirect adjustments of the national series
- compared the corresponding X-11 and SEATS adjustments

[3] SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc. in the USA and other countries. ® indicates USA registration.

3.3.1 Models

For the most part, the models that we selected continued to fit the series well as new values became available. The largest change in model fit was with the National T41 series. The selected model was (1 0 0)(1 1 0) + constant; in the fourth quarter of 2015, ϕ (nonseasonal) was 0.27, Φ (seasonal) was -0.87, and the t value for the constant was 5.68. By the fourth quarter of 2016, ϕ was 0.71, Φ was -0.81, and the constant was no longer significant, with a t value of 1.1. None of the other series had so drastic a change in the model parameter estimates. The only series with any concerns in the model diagnostics was State T09; the model selected in the fourth quarter of 2015 had significant Ljung-Box Q statistics (Ljung and Box 1978) at lags 3–5, and with each newly added quarter they remained significant at lags 3–4. It is of some minor concern that a quarterly series has a significant Ljung-Box Q statistic at lag 4, but as the diagnostic is based on the accumulated significance of autocorrelations, and the significance died out, it is not a major concern.

For some series, X-13ARIMA-SEATS selected new outliers when we added additional series values. For State T01, the program selected TC2016.1 starting when the series ended at the second quarter 2016 and for each quarter afterwards. For State T41, it selected LS2015.4 starting when the series ended with the first quarter of 2016 and for each subsequent quarter, but it selected AO2010.4 only when the series ended at the first and second quarters of 2016. These changes in outliers were not completely unexpected. If the t test statistic is close to the outlier critical value, even small differences in coefficients can result in different outlier sets.

Because the series were fairly short, we were uncertain whether the trading day variable selected for State T01 during the preliminary analysis would remain significant and continue to be estimated similarly. However, the estimated coefficient was consistent throughout, and the t value increased from 2.63 to 3.76 (for weekday activity) over the course of the monitoring.

3.3.2 Seasonal adjustment diagnostics

The QS diagnostics for all four national series indicated no evidence of residual seasonality for the direct and indirect seasonal adjustments, except for the (indirectly adjusted) National T09 containing the unadjusted local series. The significant QS results occurred only when testing the seasonally adjusted series adjusted for extreme values and the irregular series adjusted for extreme values.

If an adjustment is acceptable, that is, if after adjustment we see no evidence of residual seasonality, then we look to additional diagnostics to help decide between adjustment options. In this case we are deciding whether or not to adjust using the X-11 method or SEATS method and whether to adjust the national series directly or indirectly.

The stability diagnostics provided evidence that our adjustments were mostly reliable. However, some concerns may need addressing.

In most cases, the sliding span diagnostics provided no evidence of unstable seasonal adjustments. However, the X-11 seasonally adjusted Local T09 series intermittently had indications of unstable adjustments, whereas its SEATS-adjusted counterpart did not. Regardless of the employed seasonal adjustment procedure, both Local T40 and Local T41 displayed inconsistent stability diagnostics.

For every directly adjusted series, from the revisions history diagnostic result (Time Series Research Staff 2017), SEATS resulted in smaller average absolute revisions to the quarter-to-quarter changes more often than the X-11 adjustment. The only instances of smaller revisions from the X-11 method were the adjustments of the State T01 series when run through the fourth quarter of 2016 and of the Local T09 series when run through the third quarter of 2015.

The SEATS adjustment often resulted in smaller revisions to the seasonally adjusted series as well, with the exceptions of the State T01 and State T41 series, where half the quarters had smaller revisions from the X-11 adjustment and half had smaller revisions from the SEATS adjustment and the Local T09, State T09, indirectly adjusted National T09, and directly adjusted National T41, where the X-11 adjustment more often resulted in smaller revisions to the seasonally adjusted series.

These measures are from the revisions history stability diagnostic in X-13ARIMA-SEATS. We did not test the significance of the revisions of the estimates.

Table 3 summarizes these results.

Item Code		Method with *Smaller Revisions More Often* for	
		Seasonally Adjusted Series	Quarter-to-Quarter Change
Local	T01	SEATS	SEATS
State		tie	SEATS
National		Direct SEATS Indirect SEATS	SEATS
Local	T09	X-11	SEATS
State		X-11	SEATS
National		Direct SEATS Indirect X-11	SEATS
Local	T40	SEATS	SEATS
State		SEATS	SEATS
National		Direct SEATS Indirect SEATS	SEATS
Local	T41	SEATS	SEATS
State		tie	SEATS
National		Direct X-11 Indirect SEATS	SEATS

Table 3. Adjustment method that resulted in smaller revisions more often, of the six quarters of the monitoring phase, for the seasonally adjusted series and for the quarter-to-quarter change

A few of the adjusted-series plots show some clear differences between the corresponding X-11 and SEATS adjustments. Figure 6 presents the two seasonally adjusted Local T09 series; the SEATS adjusted series is plotted with the solid blue line; the X-11 adjusted series is plotted with the solid gray line; and the original series is plotted with the dotted gray line. There are visible differences using the two adjustments methods, with the most noticeable differences occurred in the second and third quarters of 2013. In the second quarter, the X-11 seasonally adjusted value is 8.4% smaller than the corresponding SEATS value. In the third quarter, the X-11 seasonally adjusted value is 7.9% greater than the corresponding SEATS value. That said, the two methods often have very similar results.

The plot of the State T01 adjusted series presented in Figure 7 displays very similarly adjusted series, with the largest difference between the two being 0.65%. In most of the adjusted series, X-11 and SEATS follow each other closely, but X-11 adjusted series have visible peaks whereas the SEATS adjusted series are smoother.

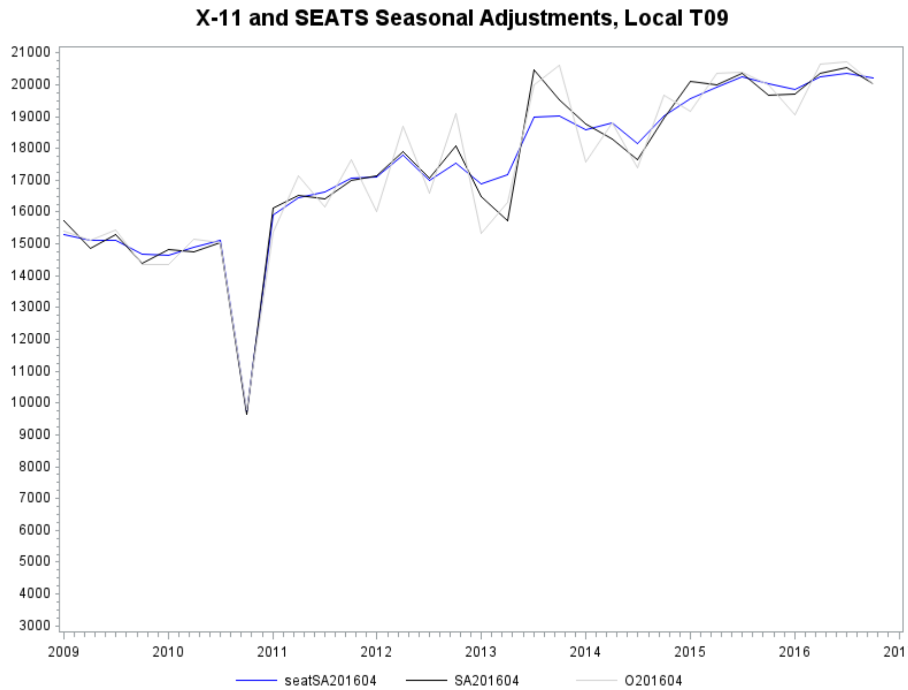

Figure 6. Local T09, the series with the clearest differences between X-11 and SEATS seasonal adjustments

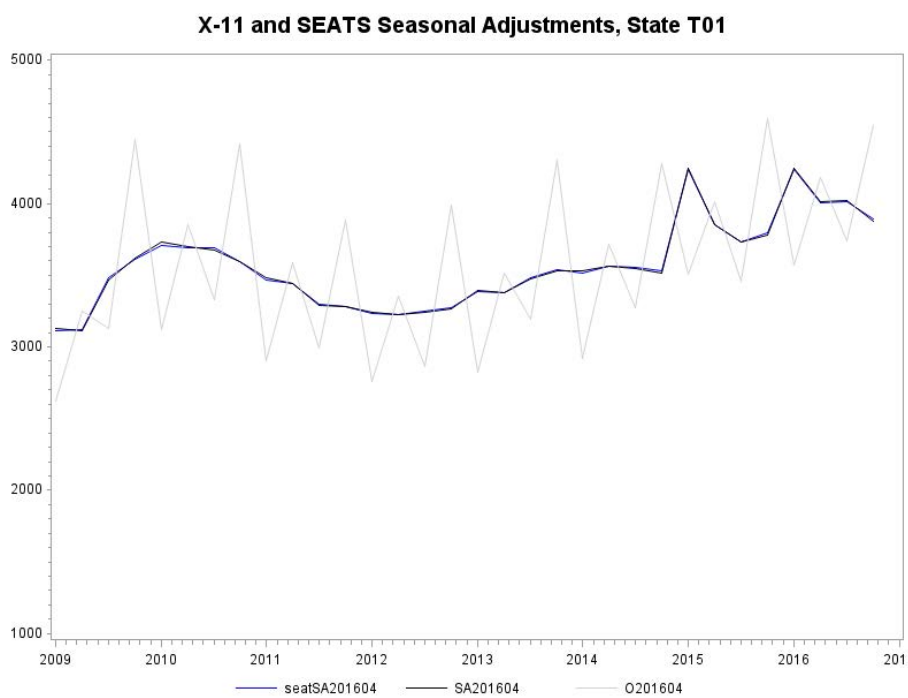

Figure 7. State T01, the series with the smallest differences between X-11 and SEATS adjustments

3.3.3 Direct vs. indirect adjustment for the national series

If we look just at minimum absolute revision as the deciding factor, then indirect adjustments would be preferable for all tax items except T41, regardless of seasonal adjustment method (X-11 or SEATS). However, we still have concerns with the adjustments for the local series. With Local T09, using the QS diagnostic, the original series adjusted for extreme values did not exhibit seasonality. In addition, the stability of the seasonal adjustment (using X-11) is in question. Twice during the monitoring period, the sliding spans diagnostics strongly indicated instability of the adjustment, and two other times, the diagnostics indicated stability but with a borderline result. Also, the State T09 model residuals showed evidence of residual seasonality.

State T40 and Local T40 both had good diagnostic results and were consistent for the most part. However, twice during the monitoring period (2015Q4 and 2016Q4), the sliding spans diagnostics indicated instability of the adjustment of the Local T40 series, both times the diagnostic results were slightly over the level considered acceptable. The seasonal patterns for the two series do not look similar, either. The indirect method yields smaller revisions for National T40, but instability in Local T40 suggests that the direct method may be better.

State T41 and Local T41 have similar seasonal patterns. Although the state series has good diagnostics, the local adjustment is not stable, according to the sliding spans diagnostics, regardless of seasonal adjustment method (X-11 or SEATS). Most of the seasonal adjustment revisions are smaller when directly seasonally adjusted using SEATS rather than indirectly adjusted. Most of the larger revisions occur under the indirect method when using SEATS. The direct method may be best in this case.

Because of concerns we had with adjustments of the local series, and in light of the fact that the Census Bureau does not publish the local series values (data users can derive the values by subtraction), we assessed the general quality of the adjustments of the state and national series. For these reasons, we decided that we would directly adjust all of the national series. Indirect seasonal adjustments of the local series will be derivable from the published national and state seasonal adjustments.

4. Conclusions and Future Work

The QTax survey had traditionally exhibited seasonal behavior in published series. Subject matter experts addressed this known seasonality in their analyses. Our research sought to more directly treat the seasonal pattern, to provide additional information to supplement but not replace what already is available. Plans are in place to publish seasonally adjusted series before the end of the current calendar year, to achieve that objective.

An advantage of starting the seasonal adjustment journey from scratch is the variety of available options with no need for concern about breaking published series. This gave us leeway to consider X-11 or SEATS for the different series, as well as direct or indirect adjustments for the national series. A disadvantage with this particular group of series was the lack of easily accessible historic expertise on the program. Anomalies were not always easily explained, which made incorporating appropriate treatments into the models challenging. Ultimately, we had to drop several years of data from the models. This latter decision made us cautious about immediate implementation in the survey. Instead, we opted to monitor the seasonal adjustment procedure on each series until the program mangers and methodologists were satisfied. This conservative approach to implementing seasonal adjustment is not unprecedented at the Census Bureau.

Even when the seasonally adjusted estimates are published, some monitoring still will be necessary. For example, we are still debating the modeling of trading day effects in selected series. More important, all Census Bureau programs that use seasonal adjustment undergo an annual review, where models and filters are subject to change.

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Note

The monitoring analysis for this paper was generated using Base SAS and SAS/GRAPH software, Version 9.4 of the SAS System for Windows.

References

Dagum, E. B. 1988. X-11-ARIMA/88 seasonal adjustment method – Foundations and users manual. Statistics Canada.

Findley, D. F., B. C. Monsell, H. B. Shulman, and M. G. Pugh. 1990. Sliding-spans diagnostics for seasonal and related adjustments. *Journal of the American Statistical Association*, Vol. 85, Iss. 410, pp. 345–355.

Findley, D. F., B. C. Monsell, W. R. Bell, M. C. Otto, and B. C. Chen. 1998. New capabilities and methods of the X-12-ARIMA seasonal adjustment program (with discussion). *Journal of Business and Economic Statistics* Vol. 16, No. 2 (April 1998), pp. 127–152. http://www.census.gov/ts/papers/jbes98.pdf.

Gómez, V. and A. Maravall. 1996. *Programs TRAMO and SEATS: Instructions for the user* (Beta Version: June 1997). Banco de España, Servicio de Estudios, DT 9628. http://www.bde.es/webbde/es/secciones/servicio/software/econom.html.

Hutchinson, R. J. and E. Wong. 2009. The rewards and challenges of seasonally adjusting a short series: seasonal adjustment research for the U. S. Census Bureau's Quarterly Services Survey. In *JSM Proceedings*, Business and Economic Statistics Section. Alexandria, VA. American Statistical Association.

Ljung, G. M. and G. E. P. Box. 1978. On a measure of lack of fit in time series models. In *Biometrika* 65, pp. 297–304.

Lytras, D. 2015. On Seasonality: Comparing X-13ARIMA-SEATS Diagnostics for Quarterly Series. In *JSM Proceedings*, Business and Economic Statistics Section. Alexandria, VA. American Statistical Association.

McDonald-Johnson, K. M., D. F. Findley, and E. Cepietz. 2009. Investigating quarterly trading day effects. In *JSM Proceedings*, Business and Economic Statistics Section. Alexandria, VA: American Statistical Association. https://www.census.gov/ts/papers/jsm09kmj.pdf.

Shiskin, J., A. H. Young, and J. C. Musgrave. 1967. *The X-11 variant of the Census method II seasonal adjustment program*. Technical Paper No. 15, U. S. Department of Commerce, U. S. Census Bureau. https://www.census.gov/ts/papers/ShiskinYoungMusgrave1967.pdf.

Time Series Research Staff. 2017. *X-13ARIMA-SEATS reference manual, accessible HTML output version, version 1.1*. Center for Statistical Research and Methodology. U. S. Census Bureau. https://www.census.gov/ts/x13as/docX13ASHTML.pdf.