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Masking of volatility by seasonal adjustment methods

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ABSTRACT

We report that the X-12 ARIMA and TRAMO–SEATS seasonal adjustment methods consistently underestimate the variability of the differenced seasonally adjusted series. We show that underestimation is due to a non-zero estimation error in estimating the seasonal component at each time period, which is the result of the use of low order seasonal filter in X12-ARIMA for estimating the seasonal component. Hence, we propose the use of high order seasonal filter for estimating the seasonal component, which helps reducing the estimation error noticeably, helps amending the underestimation problem, and helps improving the forecasting accuracy of the series. In TRAMO–SEATS, Airline model is found to deliver the best seasonal filter among other ARIMA models.

1. Introduction

Seasonal adjustment of a time series means removing the seasonal component from a seasonal time series. The two seasonal adjustment methods used for estimating the seasonal component, X-12 ARIMA and TRAMO–SEATS, are based on different philosophies/methodologies. Thornton (2011) recently compares Butterworth low-pass filter for the UK new car registration with that of the X-12 ARIMA and the TRAMO–SEATS filters. The US Census Bureau's non-parametric seasonal adjustment method X-12 ARIMA (Findlay et al., 1998) uses moving average procedures (Shiskin et al., 1967) for estimating the seasonal component in each stage of its two stage iterative procedure. In the first stage, it uses $S_{3\times3}$ moving averages of SI differences or ratios, alternatively known as the seasonal filter. Following the Lothian procedure, the X-12 ARIMA chooses one of the following filters among $S_{3\times3}$, $S_{3\times5}$, $S_{3\times9}$, and $S_{3\times15}$ in its second stage. In almost all cases it ends up choosing the $S_{3\times5}$ filter. The TRAMO–SEATS[1] procedure partitions the spectrum of the seasonal ARIMA model in order to estimate the seasonal components. The default ARIMA model in TRAMO–SEATS is the Airline model of the form of $(1-L^D)(1-L^d)y_t = (1+\theta L)(1+\Theta_m L)\varepsilon_t$, where D, and d are seasonal and non-seasonal differences respectively, and θ and Θ_m are the non-seasonal and seasonal MA parts respectively, with m denoting the frequency of the data. Moreover, the Airline model is the model that TRAMO–SEATS selects from among other ARIMA models in many cases (Fischer and Planas, 2000). A quality seasonal adjustment requires the estimation of the seasonal component in such a way that the irregular component is not contaminated by it, in terms of under- or over-estimation of either the seasonal or irregular component variation (Burman, 1980).

In fact, Miller and Williams (2004) documented the fact that the X-12 ARIMA's seasonal filter overestimates seasonal variation. Alternatively, X-12 ARIMA underestimates the variability of the log differenced seasonally adjusted series. Miller & Williams provide a solution to the problem of overestimation of the seasonal variation issue, but it works outside the X-12 ARIMA framework. The procedure is to dampen or smooth the seasonal variation by using one or other of the two types of estimators externally to the X-12 ARIMA estimated seasonal factors, namely the Global shrinkage estimator and the Local shrinkage estimator. The Global damping estimator is based on the shrinkage estimator of James and Stein (1961), whereas the Local damping is done by the method of Lemon and Krutchkoff (1969). Actually there have been a variety of works done on Stein-rule estimators including in the regression context, see for instance, Shalabh (1998), Chaturvedi and Shalabh (2004), and Shalabha et al. (2009) among others. The Local shrinkage estimator works well, especially for time series in which the random variation dominates the seasonal variation (Findley et al., 2004). This makes

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[1] TRAMO is an abbreviation of Time Series Regression with ARIMA Noise Missing Observations and Outliers, and SEATS is an abbreviation of Signal Extraction in ARIMA Time Series. TRAMO is a program for the estimation and forecasting of regression models with possibly ARIMA errors. SEATS is a program for the estimation of unobserved time series components following the ARIMA-model-based method. It uses a signal extraction technique with an ARIMA model to estimate the time series components. T–S (see Gomez, 1992; Gomez and Maravall, 1994, 1997) was developed from a program built by Burman (1980). Burman's program partitions the spectrum of the seasonal ARIMA model into trend, seasonal and irregular components. A nice application of the TRAMO–SEATS appears in somewhat different contexts of direct vs. indirect seasonal adjustment in Maravall (2006).

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sense, as the aim of the Miller & Williams procedure is to smooth the seasonal variation, which is overestimated by the X-12 ARIMA default method. We find that this is because the X-12 ARIMA's default setting picks up the low order seasonal filter or moving average of SI (seasonal-irregular) ratios, $S_{3\times3}$ in the first stage and mostly $S_{3\times5}$ in the second stage of the seasonal adjustment.

Findley et al. (2004) admitted the gains from Local shrinkage to the seasonal factors, but raised major concerns about the methodology of the Miller & Williams procedure, as it lacks theoretical justifications and practical implementations. These are the reasons why Miller & Williams' procedure is not adopted in X-12/13 ARIMA. Instead, the TRAMO–SEATS procedure is on the way to being implemented in X-13-ARIMA–SEATS, which aims to deliver gains similar to those of the Miller & Williams estimator for series in which the random variation dominates the seasonal variation (Findley et al., 2004).

We contribute to the above discussed literature. We raise the question as to whether we can achieve Miller & Williams' (i.e., no underestimation of the variance of differenced seasonally adjusted series and better seasonal adjustments) within the X-12 ARIMA framework. The main advantage of this is that it is based on the X12-ARIMA methodology and offers easy implementation. We analyze the same question for the TRAMO–SEATS seasonal adjustment, as it is used globally second to the X-12 ARIMA method, and is gradually becoming the part of the X-12 ARIMA method. In addition, it is also interesting to analyze TRAMO–SEATS for such an issue, as TRAMO–SEATS's estimated seasonal component for the Airline model can be very close to that of X-12 ARIMA (Planas and Depoutot, 2002). Hence, TRAMO–SEATS may be no different to X-12 ARIMA on the issue of overestimation of the seasonal variation. However, it is not known whether the TRAMO–SEATS seasonal filters come close to the X-12 ARIMA filters when the data generating process (DGP) is not equivalent to the Airline model. In this case, X-12 ARIMA may produce better seasonal estimates for such series than TRAMO–SEATS, due to X-12 ARIMA's nonparametric nature and its tendency to match the seasonal filter of any DGP to the order of the moving averages of SI differences or ratios. This is the main advantage which X-12 ARIMA could have over TRAMO–SEATS.

We report that the X-12 ARIMA and TRAMO–SEATS seasonal adjustment methods consistently under-estimate the variability of the differenced seasonally adjusted series. We show that this under-estimation is due to a non-zero estimation error in estimating the seasonal component at each time period, which is the result of the use of a suboptimal (generally low) order seasonal filter in X12-ARIMA, suggested for estimating the seasonal component by its default method. Hence, the use of an optimal (generally high) order seasonal filter for estimating the seasonal component in X-12 ARIMA helps reduce the estimation error noticeably, helps amend the under-estimation problem, and helps improve the forecasting accuracy of the series. In TRAMO–SEATS, the Airline model is found to deliver the best seasonal filter of all ARIMA models. We find that the seasonal parameter estimate Θ_m comes close to its invertibility limit of -1, which leaves almost no space for TRAMO–SEATS to produce a frequency transfer function which could be close to X-12 ARIMA's filter. This is the main advantage that X-12 ARIMA has over TRAMO–SEATS which we report.

The paper is structured as follows: Section 2 provides the background for our research question of volatility under-estimation by the two seasonal adjustment methods. In Section 3, we show the causes of the under-estimation of volatility by the seasonal adjustment methods. In Section 4, we elaborate on the use of higher order seasonal filters in X-12 ARIMA for smoothing the SI (seasonal-irregular) series. In Section 5, we show the masking of the volatility by the seasonal adjustment methods. In Section 6, we prescribe a remedial measure for the volatility under-estimation problem in X-12 ARIMA. In the second to the last section, we show the gains obtained using the prescribed remedial measure in real life data. The last section concludes the paper.

2. Overestimation of seasonal variation

The aim of the Global and Local shrinkage estimators of Miller & Williams' procedure is to dampen the seasonal variation of the X-12 ARIMA estimated seasonal factors using shrinkage estimators. We look this issue from the perspective of the (moving) variance of the log differenced seasonally adjusted series. The plot of the variance of the log differenced seasonally adjusted data is plotted in Fig. 1. TRAMOS–SEATS and X-12 ARIMA are compared and analyzed similarly below. We assume that the time series data are in logarithmic (log) form and that the seasonal component is therefore additive (rather than multiplicative) in X-12 ARIMA. In Section 7, we allow seasonal adjustments to be conducted in X-12 ARIMA in additive and multiplicative modes, with a log transformation and no transformation to the data, respectively. The findings of this paper are invariant to the seasonal adjustment mode.

The models, estimation method and simulation design behind Fig. 1 are discussed in detail in the upcoming sections. The main observations from Fig. 1 which we will highlight here are the following:

- the variance of the log differenced seasonally adjusted series is consistently under-estimated by X-12 ARIMA (default) and TRAMO–SEATS relative to the true variance;
- the X-12 ARIMA seasonal filter tends to match the non-seasonal part of any DGP, comparing the variance from X-12 ARIMA's $S_{3\times15}$ filter to the true variance; and
- the improvement of seasonal adjustment in TRAMO–SEATS seasonal filter is limited when the DGP does not match the Airline model.

These points imply that:

- the default seasonal filters in X-12 ARIMA and TRAMO–SEATS are not optimal for an unknown DGP;
- the X-12 ARIMA seasonal filter has an advantage over the TRAMO–SEATS due to its non-parametric nature, which can help in matching the seasonal filter of any seasonal DGP, meaning that we do not need to go out of the X-12 ARIMA framework, as was suggested by Miller & Williams; and
- the TRAMO–SEATS Airline model cannot do any better than this for matching the seasonal filter of the true seasonal DGP.

These findings are robust to various DGPs and parameter values, as we actually repeated the exercise for different parameter values, with results which are not shown here, and the story remains the same. The true variance of the non-seasonal part of the DGP is shown by the black line. We have used seven different DGPs, which are referred to in the figure as models. The X-12 ARIMA (default) procedure underestimates the variance of the corresponding non-seasonal part of the series, as is shown by the red line. The green line indicates that TRAMO–SEATS performs similarly.

The tendency of the X-12 ARIMA to match the seasonal filter of the DGP can be traced by the variance of the non-seasonal part, which increases with the length of the seasonal filter (from default: $S_{3\times3}$ and $S_{3\times5}$ in the first and second iterations to the highest seasonal filter, $S_{3\times15}$), as is depicted by the blue line. Miller & Williams presented the same idea of damping the seasonal variation by using the shrinkage estimators to X-12 ARIMA estimated seasonal factors out of X-12 ARIMA. We do the same, but employ a higher order seasonal filter of X-12 ARIMA within X-12 ARIMA to dampen the seasonal variation, and analyze the same issue for TRAMO–SEATS. TRAMO–SEATS (default) does a far better job than the X-12 ARIMA (default) procedure; however, its improvement gets constrained by the seasonal parameter Θ_m, as its estimate comes close to the invertibility limit of -1 in almost all cases. Our results complement Fischer & Planas' finding