Analysis of Crisis Effects via Maximum Entropy

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This report is released to inform interested parties of research and to encourage discussion. The views expressed on statistical issues are those of the author and not those of the U.S. Census Bureau.

Overview

- Crises (such as the Covid-19 epidemic) can affect economic time series by distorting historical trend and seasonal patterns with sustained streams of extreme values in the data.

- Our goal is to identify, estimate, and remove extremes; this is important for the task of seasonal adjustment, for example.

- In this paper the maximum entropy framework (which identifies and adjusts for additive outliers) is extended to a generalized class of extreme values, including level shifts, temporary changes, and seasonal outliers.

Specific Results

- The paper shows how to express and compute the time series' likelihood function, when the process is non-stationary, may have missing values, and has extremes present.

- Given a fitted time series model, the paper discusses extreme-value adjustment using optimal linear projections based on the maximum entropy framework; there is also a test statistic to directly compare two specifications of extremes.

- After removing (or shrinking) extremes, the paper shows how to filter the sample and produce seasonal adjustments; the uncertainty is driven both by extreme-value adjustment and forecast extension.

Maximum Entropy Framework

- The idea is to find linear transformations of the data that remove extreme effects entirely, leaving the "regular" values, which correspond to a Gaussian process, having higher entropy.

- The extreme effects are modeled with impulse regressors that have stochastic coefficients. This results in the extremes being modeled in the time series' covariances rather than in the mean function (as happens in RegARIMA modeling).

- If the analyst specifies two nested sets of extremes, we can fit the time series model in either case, and compute a test statistic to compare extreme specifications.

Extreme Value Adjustment

- Extreme-value adjustments are defined by linear projection (i.e., formulas involving covariances) onto the regular values; this is a maximum entropy transformation of the sample. The paper discusses shrinkage as well.

- We may also wish to impute missing values (which are assumed to be regular), forecast extend the sample (do allow for filtering), incorporate deterministic effects (such as holiday regressors), and filter the extreme-value adjusted sample.

- The paper shows how to decompose the time series sample additively into signal and noise components (e.g., non-seasonal and seasonal components) with the corresponding measures of mean squared error (MSE).

An Illustration

We provide an illustration of the paper's techniques:

- National Unemployment Insurance Weekly Claims, January 7, 1967 through April 22, 2023. Claims surged to previously unseen levels in the opening of the pandemic in the U.S. (March 21, 2020).

- An extreme specification with 3 level shifts (LS) and 9 additive outliers (AO) is identified and tested. A SARIMA model is fitted.

- We display the extreme-value adjustment (with 20 forecasts and backcasts), and also a seasonal adjustment using a custom weekly filter.

Claims: Data

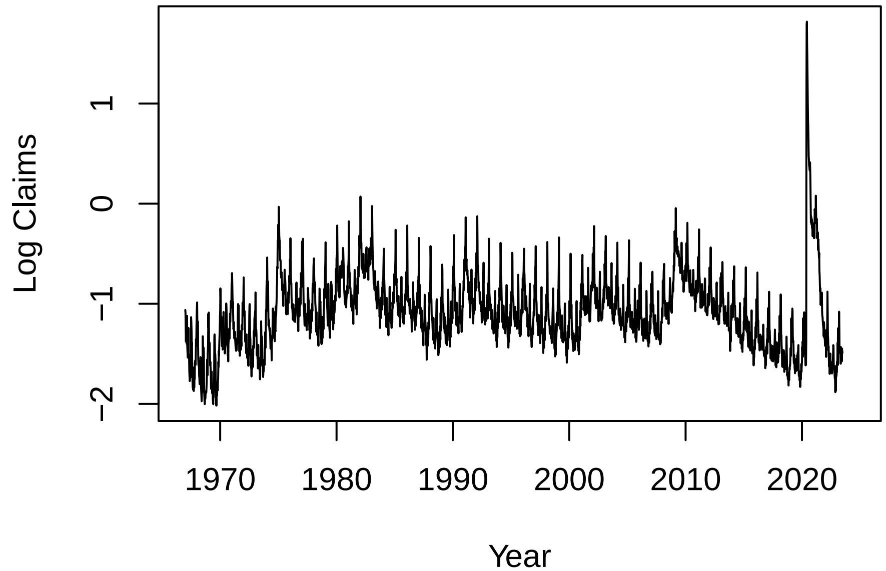

Figure 1: Logarithm of National Unemployment Insurance Weekly Claims Data

Claims: Extreme Identification

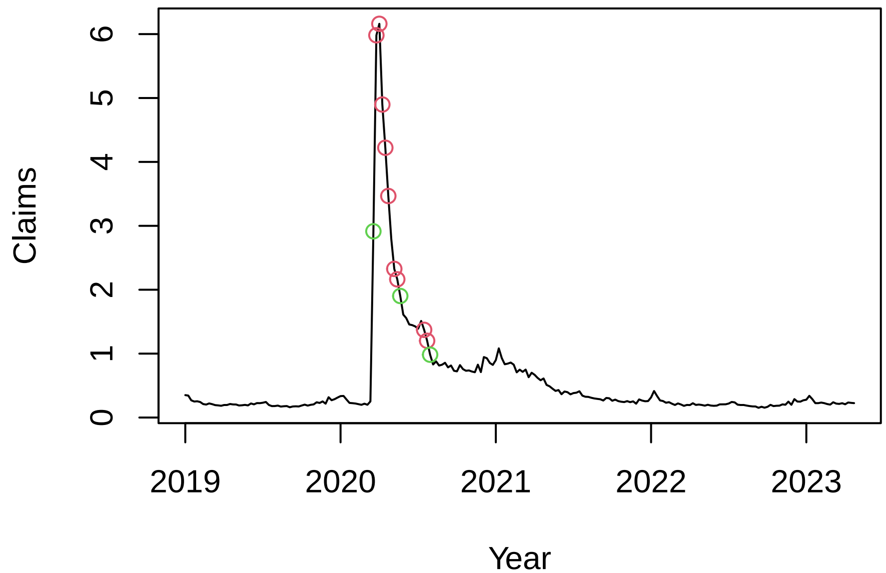

Figure 2: Extremes in the log Claims data, marked with circles: LS (green) and AO (red).

Claims: Extreme-value Adjustment

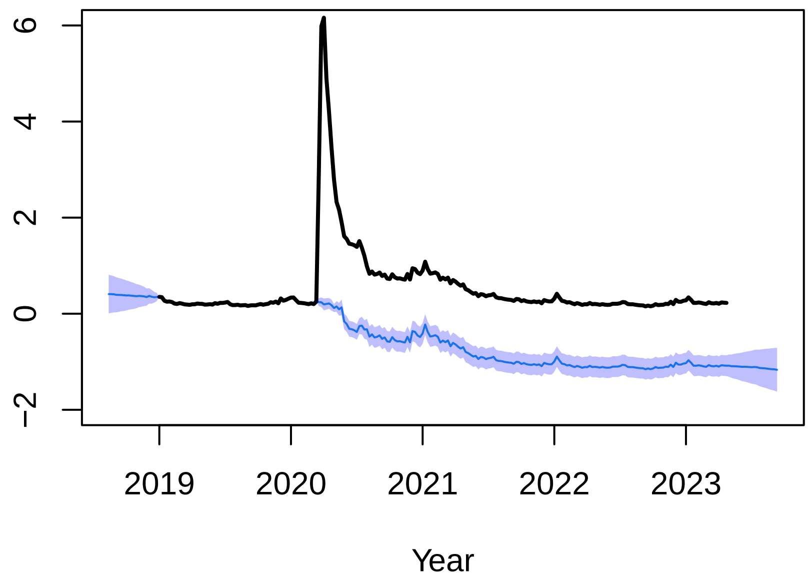

Figure 3: Extreme-value adjustment of log Claims data. Original data in black, and full shrinkage adjustment in blue.

Claims: Seasonal Adjustment

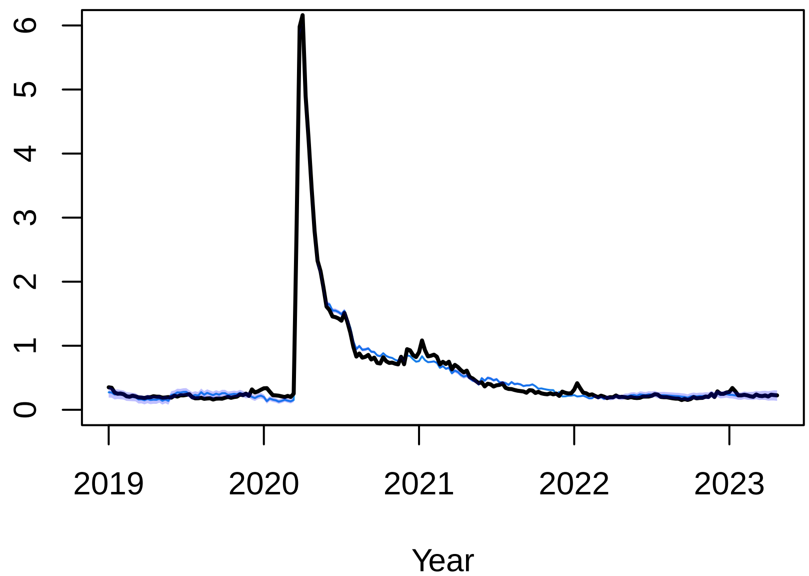

Figure 4: Seasonal adjustment of log Claims data. Original data in black, and seasonal adjustment in blue.

Conclusion

1. Maximum entropy methodology allows fitting, testing of extreme specification, extreme-value adjustment, and filtering with uncertainty measures.

2. Illustrated on Unemployment Insurance Claims data impacted by Covid-19.

3. All routines written in R, being updated on Github: `https://github.com/tuckermcelroy/maxentropy`

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